Exchange Rate Dynamics and its Effect on Macroeconomic Volatility in Selected CEE Countries

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Abstract

Structural differences between countries and loss of exchange rate and monetary policy adjustment channels are important aspects to consider when forming a currency union. In this paper we study the role of exchange rate shocks in generating macroeconomic volatility in selected Central and East European countries. We also analyze the relative importance of asymmetric shocks to consider structural differences between the CEE countries and the Eurozone. We use two-country structural VAR models identified by the sign restriction. Our findings suggest that there are structural differences both within the group of CEE countries as well as in comparison with their Euroarea counterparts. We assess the dynamic properties of macro-variables and examine if the exchange rate could be considered a shock-absorber. We identify countries where shocks are predominantly symmetric relative to the neighbor, as well as countries with strong contribution of real exchange rate shocks. In general, for all considered countries the results suggest the shock absorbing nature of real exchange rate. Finally, the significant role of the symmetric monetary policy shocks for movement in real exchange rates is found for some of the countries.

JEL Codes: C32, E32, F31, F41.

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1. Introduction

There is a tradition in theoretical models (going back to Mundell-Fleming-Dornbusch model) to consider real exchange rate as an automatic stabilization mechanism. Evidence from the empirical literature is, however, mixed as there exists economies where the exchange rate is a source of business cycles fluctuations and imbalances for the economy. The role of the real exchange rate is becomes especially relevant when considering membership of economies in the optimal currency area or the appropriateness of common monetary policy stance for a group of economies.

The aim of this work is to study the role of the real exchange rate shocks for the macroeconomic volatility and also dynamic effects of the symmetric and asymmetric shocks on the set of macroeconomic variables. As we study a group of diverse economies which are via close trade links exposed to common currency area, the direction of a shock impact on the economy is essential for our analysis, rather than the idiosyncratic or common origin of the shock.

Symmetric shocks are identified as shocks that generate an effect which has the same sign in economies under investigation. In contrast, asymmetric shocks have the opposite impact in both economies.

Questions of the role of the real exchange rate and relative importance of the asymmetric shocks are especially relevant for Central and Eastern European Countries. As some of these countries are already members of the Eurozone and some are obliged to enter it in the near future, the adoption of common monetary policy stance might be a substantial cost for these countries. Therefore, we examine the the role of the real exchange rate and the relative importance of symmetric and asymmetric shocks for a group of Central and Eastern Europe (CEE), that includes Czech Republic, Slovakia, Poland, Hungary, Lithuania, Latvia, Estonia, Slovenia, Bulgaria and Romania.

This analysis employs the sign restriction method for identification of structural VAR model. This method allows us to focus on effect of the shock that is crucial when considering its effect on the economy. The sign restriction method was introduced by Uhlig (2005) and since then has become a popular tool. We elaborate approach of Scholl and Uhlig (2008), Mallick and Rafiq (2008) and Peersman (2011) to analyze the contribution of shocks to macroeconomic volatility.

To identify the shocks, we simplify restrictions introduced by Peersman (2011) but we still keep the distinction between symmetric and asymmetric shocks. Our implementation also takes into account a thorough discussion of sign restriction method and its benefits and shortcomings is presented by Fry and Pagan (2011).

Our findings suggest that the CEE region is formed by heterogeneous countries with asymmetries present both within the region and vis-a-vis the rest of the Eurozone. These asymmetries are partially attributable to different monetary policy and exchange rate regimes (for non-member countries) and to structural differences (for example, TFP levels, level of nominal prices). At the same time, our results are consistent with the shock absorption role of the real exchange rate for CEE countries.

We start our paper by addressing the theoretical role of the real exchange rate as a shock absorber and reviewing the relevant literature in Section 2. We find that empirical evidence on the role of the exchange rate is mixed. Section 3 describes the sign restriction method and its implementation in our study. In Section 4 we analyze the property of the data and exchange rate regimes in the countries under consideration. The estimation and identification of the structural VAR model setup is presented in Section 5, where we discuss the restrictions in use. Section 6 considers the relative importance of asymmetric shocks and role of exchange rate in absorbing or generating shocks in the selected countries. Finally, Section 7 describes the relevance of our findings to the debate on optimal currency area and acknowledges limitations of our study.

2. Exchange Rate as a Source of Shocks or a Shock Absorber

Theoretical discussion of whether the real exchange rate can act as a buffer against shocks goes back to a paper by Obstfeld et al. (1985), featuring the Mundell-Fleming-Dornbusch model. In this model output, prices and interest rates are affected by supply, demand and nominal shocks. The equation on the real exchange rate reflects its response to shocks and whether it is helpful in restoring the equilibrium. This theory underlines a framework of considering the real exchange rate as shock absorber. The debate is of particular interest when considering the choice of exchange rate regime and optimal currency areas. At the same time the exchange rates themselves exhibit large deviations from equilibrium values, implying that they could be influenced by idiosyncratic shocks. These deviations, in turn, can affect output and prices. In this regard, the question has been if these exchange rate shocks propagate further in the economy, and if the real exchange rate is itself a source of volatility.

There is a strand of empirical literature assessing whether real exchange rates are shock-absorbers or sources of shocks. Clarida and Gali (1994) state that a demand shock explains most of the variance in the real exchange rate. Nominal shocks, including exchange rate shock, were found unimportant. The study concluded, therefore, that the real exchange rate acts as a shock absorber. Recent work by Juvenal (2011) supports these findings that demand shocks are important for generating real exchange rate fluctuations in the US vis-a-vis rest of the world. Farrant and Peersman (2006), using a different methodology, come to a different conclusion for a similar set of countries considered. They show that real exchange rate shocks are important determinants of exchange rate fluctuations, suggesting that the exchange rate is a source of volatility. On the other side of the ocean, there are studies inspired by European economic integration, focusing on whether the real exchange rate towards euro is insulating a country against the shock or whether it is an undesirable source of volatility. Peersman (2011) studies UK vis-a-vis Euro, Amisano et al. (2009) for Italy vis-a-vis Euro, Artis and Ehrmann (2006) for UK, Denmark and Sweden vis-a-vis Euro, and Canada vis-a-vis US. These studies did not find the real exchange rate to be a shock absorber, and for some countries fluctuations on the exchange markets were important sources of volatility. In contrast, Thomas (1997) found that 60 percent of fluctuations in the real Sweden-Euro exchange rate are explained by real shocks, suggesting there is a potential that the real exchange rate plays shock absorbing role. The paper uses identification methodology as in Clarida and Gali (1994), which was criticized by Farrant and Peersman (2006) as too restrictive.

An important aspect to consider when studying exchange rate absorption properties is whether shocks in the region are mostly symmetric or asymmetric. By asymmetric we mean a shock causing the opposite monetary policy reaction, as defined in Artis and Ehrmann (2006). The nature of opposite policy responses lies in countries' structural differences, labor market flexibilities or fiscal policies. When the countries are closely related in terms of their economic structure, the shocks are likely to cause symmetric responses. In this case, two economies are moving in the same direction and strong reaction of the exchange rate is not expected. If, however, there are important asymmetries between the countries and shocks cause predominantly asymmetric responses, the exchange rate can respond to the shock and damp its propagation further in the economy. Therefore, in this paper we address the relative importance of symmetric and asymmetric shocks to analyze the potential role of the real exchange rate as shock absorber.

In addition to absorbing shocks, exchange rates can be themselves a source of volatility. High volatility in the exchange rate market translates into volatility of prices and, potentially, output. In this regard, we study how much of the real exchange rate variation is attributed to an idiosyncratic shock. If this contribution is high, it suggests that the exchange rate breeds its own shock. We then assess the contribution of the idiosyncratic shock to the volatility of output and prices.

3. Implementing Sign Restrictions

In this work, we estimate a structural VAR (SVAR) model of a small open economy. The common approaches to identify SVAR impose various short or long-term restrictions on the responses of the variables to shocks or impose contemporaneous restrictions via recursive ordering. As Uhlig (2005) summarizes, the ordering approach often leads to the emergence of anomalies such as the price puzzle or delayed overshooting puzzles. Also, Farrant and Peersman (2006) show that long-term zero response restrictions can deliver biased results.

Therefore, we employ the sign restrictions identification method pioneered by Faust (1998) and further developed by Uhlig (2005). In the sign restriction approach, shocks are identified by imposing restrictions on the signs of the impulse responses to structural shocks. These restrictions are usually imposed in the short to medium term to represent the effects of the structural shocks. The restrictions applied to the impulse responses can avoid the different puzzles that can occur when alternative estimation procedures are employed.

A structural VAR model of order p with n variables, where X is a vector of endogenous variables, can be stated as:

$$BX_t = A(p)X_{t-1} + \varepsilon_t. \tag{3.1}$$

Here, $A(p)$ is a polynomial of order p of matrices of size $n \times n$; B is a matrix of size $n \times n$; and ε_t is an $n \times 1$ vector of normally i.i.d. shock disturbances with zero mean and diagonal variance matrix Σ. The reduced-form VAR can be then written:

$$X_t = \Pi(p)X_{t-1} + e_t, \tag{3.2}$$

where $\Pi(L) = B^{-1}A(L)$ and e_t is an $n \times 1$ vector of normally i.i.d. shock disturbances with zero mean and variance-covariance matrix V. The general-form shocks are related to the structural representation of the model in the following manner:

$$e_t = B^{-1}\varepsilon_t \qquad V = E(e_t e_t') = HH'. \tag{3.3}$$

The impulse responses of the structural representation are characterized by impulse matrix B^{-1}. The identification problem arises if there are not enough restrictions to pin down V as $HH' = B^{-1}\Sigma B^{-1'}$. The multiplicity originates from the orthonormal property of matrices, as for any orthonormal matrix $Q, V = (HQ)(HQ)'$. Thus e_t has the same variance matrix but is associated with different impulse responses generated by impulse matrix $B^{-1}Q$.

As Berg (2010) claims, the ability to generate multiple impulse responses makes the sign restriction approach more advantageous then recursive identification schemes. The large number of available factorizations, together with choice of restrictions, allows us to avoid counterintuitive results. The IRIS toolbox used in our paper implements the following algorithm based on procedure by Berg (2010), which was originated by Rubio-Ramírez et al. (2005).

First, the reduced-form VAR model is estimated to obtain matrix V. Second, the lower triangular factor of V is computed. Third, a random $n \times n$ matrix W is drawn from the multivariate standard normal distribution. Further, W can be factorized $W = QR$, so that $QQ' = QQ' = I$ and R is the upper triangular matrix. Fourth, the impulse response matrix $B^{-1}Q$ is created and responses are calculated. Finally, the restrictions are checked and if all are fulfilled the draw is kept; otherwise it is discarded. This procedure is repeated until the targeted number of successful draws is collected.

Theoretically, there can be an infinite number of the admissible set of parameters. The popular approach is to report median response at each horizon for each variable separately. This approach suffers from the fact that these separate median responses originate from different models (different parameterizations). For consistency in reporting results, we use the closest-to-median approach proposed by Fry and Pagan (2011). The representative model is parameterized by solution to the following problem given by:

$$\min_j M(j) \quad = \quad \sum_{i=1}^{q} (\overline{\phi_i} - \phi_j)(\overline{\phi_i} - \phi_j)', \tag{3.4}$$

where the search runs over all successful draws j, and $\overline{\phi_i}$ is the median impulse for each period i over all successful draws ϕ_j. Here, $\overline{\phi_i}$ and ϕ_js are $n \times n$ matrices.

In order to analyze the role of the exchange rate in generating economic volatility, we decompose the variance of the model variables. Forecast error variance decomposition indicates how much of the forecast error variance of each of the variables can be explained by exogenous shocks to the other variables. In accordance with the Fry and Pagan (2011) critique of the multiplicity of parameterizations, the variance decomposition of the closest-to-median model is analyzed.

4. Data

We consider the following ten countries as the domestic country in the framework of the two country model: Bulgaria, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Romania, Slovakia and Slovenia. For each of these countries, the foreign counterpart is its effective foreign aggregate of the remaining European Union countries. These effective indicators are constructed as weighted averages from the corresponding series for Eurozone countries. Weights used originate from the shares of domestic export for each country under consideration.

The time series used in this work originate from the Eurostat database and for each country, we have to take into account the specific data available. For most of the countries, the sample period covers the period from the first quarter of 1998 to the fourth quarter of 2013, so there are 63 observations. All the series used in the analysis are seasonally adjusted and converted to the quarterly frequency.

For each of the CEE countries considered and construction of the foreign aggregate, the real gross domestic product (GDP) is constructed by deflating the nominal GDP by its deflator. As the price index the harmonized index of consumer prices (HICP) is used

Short-term interest rates are described by the 3-month money market rates that apply to interbank deposits or loans with an original maturity of three months. As Slovenia adopted the Euro in 2007, followed by Slovakia in 2009 and Estonia in 2011, their three-month interbank rate is represented by the Euro interbank offered rate (Euribor) after adoption. Latvia joined the Euro in 2014 but as our sample ends by the fourth quarter of 2013, this does not affect our data.

As the measure of the real exchange rate, the effective real exchange rate of domestic currency against that of the other European countries is used. The real effective exchange rate aims to assess a country's (or currency area's) price or cost competitiveness relative to its principal competitors in international markets. Changes in real exchange rate depend not only on exchange rate movements but also on cost and price trends. Series from Eurostat use export weights to calculate real exchange rate, reflecting not only competition in the home markets of the various competitors, but also competition in export markets elsewhere. A rise in the real exchange rate means a loss of competitiveness.

Table 1 presents a summary of the recent monetary policy settings in the countries considered over 1998–2013. Although CEE accession countries aim to adopt the Euro in the medium-term future, their experience with exchange rate regimes is quite diverse. Countries in the sample experienced transition from centrally planned to market driven economies in the early 1990's and now are converging to the common market of European Union. This summary shows that inflation targeting has gained popularity in many CEE countries over the period, while exchange rate focused monetary is still very popular.

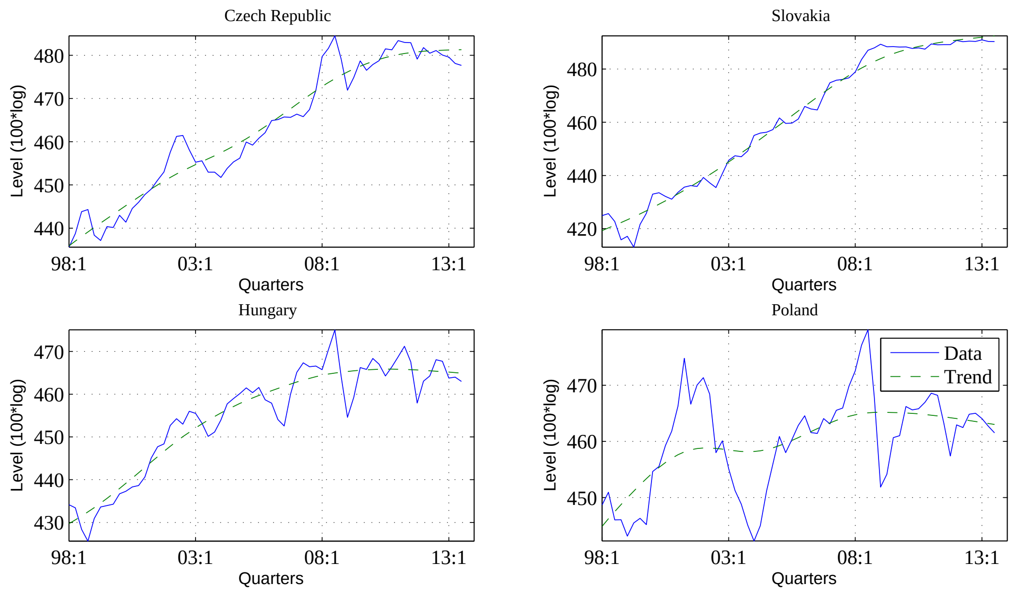
Table 1: Monetary Policy Strategies

Country	Exchange Rate Regime	Monetary Policy	Note
Bulgaria	Peg to Euro	Exchange rate targeting	Currency board
Czech Republic	Free float	Inflation targeting	
Estonia	Peg to Euro	Exchange rate targeting	Euro - 2011
Hungary	Managed/Free float	Ex. rate+Inflation targeting	Free float from 2008
Latvia	Conventional fixed peg	Exchange rate targeting	Euro - 2014
Lithuania	Managed float	Exchange rate targeting	Euro - 2015
Poland	Managed/Free float	Inflation targeting	Free float from 2000
Romania	Managed float	Ex. rate+Inflation targeting	
Slovakia	Managed float	Inflation targeting	Euro - 2009
Slovenia	Managed float	Ex. rate+Inflation targeting	Euro - 2007

Figure 1 documents the presence of trends in the real exchange rate for countries with diverse characteristics and choices of monetary policy. Transformation and convergence processes are mainly fueled by faster productivity growth in the countries considered, compared to the core countries of the European Union. Also, as many CEE economies use inflation targeting, trends are also present in the price level data. Therefore, a trend-cycle transformation of data is needed to handle the presence of these trends. However, the convergence trajectories of the countries differ significantly as they had to cope with with changes in their economic structures, their policies and differences in the initial conditions of the convergence process. This figure also suggests that these trends vary over the considered period, therefore we assume that there are no common trends in the convergence process.

To remove time varying trends under assumption of common trend component absence, we consider univariate trend-cycle decomposition for all variables in the model. To do this, we detrend the data with HP filter by setting $\lambda = 1600$ after taking logs and rescaling the series by a factor of 100. We

Figure 1: Real Exchange Rates: Data and Trends



believe that this approach is flexible enough to remove time varying trends and handle the presence of the unit roots in the data and anchored expectation in developed countries. The advantageous product of the applied transformation procedure is transformation of all the data in to percentage deviations from the trend, thus easing interpretation of results.

5. Imposing Identification Restrictions

The origins of sign restrictions used to examine the relationship between real exchange rate and business cycle can be traced to a two-country model with sticky prices derived by Obstfeld et al. (1985). Based on the two country model, Clarida and Gali (1994) present a parsimonious model where variables under consideration are in the form of domestic to foreign variable ratio. This approach was adopted by a stream of structural VAR studies such as Thomas (1997), Artis and Ehrmann (2006) and Amisano et al. (2009). This approach is based on reasoning that the real exchange rate itself is a relative variable and that only relative or asymmetric shocks are interesting, as the symmetric shocks do not require any adjustment of the real exchange rate. These models feature four variables: relative GDP (domestic to foreign), relative price and relative interest rate, together with the real exchange rate.

Models in relative terms are not able to identify symmetric shocks, and thus do not provide information on the comparative importance of asymmetric shocks with respect to symmetric shocks. As Peersman (2011) points, it is possible that the asymmetric shocks are not the major source of the volatility. In such case, the relative model focuses only on a small portion of the variance. Nevertheless due to the inability to judge the comparative importance of symmetric and asymmetric shocks, the relative form of variables implies the strong restriction of the transmission of symmetric (common) shocks in the compared economies is the same in amplitude and timing. As in relative models any deviation from one-to-one propagation of a common shock is rendered asymmetric, it is also necessary to consider differences in transmission mechanisms before judging the importance of asymmetric shocks.

Following Peersman (2011), we apply an extended version of the VAR model that is able to separate symmetric and asymmetric shocks. In comparison to relative models, the identification scheme used not only takes into account the presence of symmetric supply, demand and policy shocks, but also their asymmetric counterparts. Recall that asymmetric shocks are identified as those calling for opposite movements in interest rates. The interpretation of identified shocks is a standard in the literature. Positive supply shock increases output and reduces prices and positive demand shock is characterized by increasing prices and output, while restrictive monetary policy leads to reduction of output and prices. The exchange rate shock is identified so that exchange rate appreciation (loss of competitiveness) leads to restrictive influence on the domestic economy. As shocks are identified by their effects on economies, this scheme does abstract from a one-to-one form of symmetry.

Variables used in the applied VAR model set up the following vector: $X_t = \{y_t, p_t, i_t, q_t, y_t^*, p_t^*, i_t^*\}$, where y_t is real GDP gap, p_t is consumer price index gap, i_t is interest rate gap and q_t is the gap in the real exchange rate (increasing value reflects loss of domestic economy competitiveness), while y_t^* is effective foreign real GDP gap, p_t is the gap in effective foreign consumer price index and i_t is gap of effective foreign interest rate.

In the structural VAR model, we identify seven structural shocks: a symmetric supply shock, a symmetric demand shock, and a symmetric monetary policy shock, three corresponding asymmetric shocks and a real exchange rate shock. Restrictions presented in Table 2 are consistent with the responses of the two-country theoretical model presented in Clarida and Gali (1994), Farrant and Peersman (2006) and Peersman (2011).[1] This complex set of restrictions focuses on the identification of the symmetric, asymmetric shocks and real exchange rate shock.

Table 2: Sign Restrictions – Individual Shocks

Variable Structural Shock	y_t	p_t	i_t	y_t^*	p_t^*	i_t^*	q_t
Symmetric Supply	≥ 0	≤ 0	≤ 0	≥ 0	≤ 0	≤ 0	
Symmetric Demand	≥ 0	≥ 0	≥ 0	≥ 0	≥ 0	≥ 0	
Symmetric Monetary Policy	≤ 0	≤ 0	≥ 0	≤ 0	≤ 0	≥ 0	
Asymmetric Supply	≥ 0	≤ 0	≤ 0	≤ 0	≥ 0	≥ 0	
Asymmetric demand	≥ 0	≥ 0	≥ 0	≤ 0	≤ 0	≤ 0	≥ 0
Asymmetric Monetary Policy	≤ 0	≤ 0	≥ 0	≥ 0	≥ 0	≤ 0	≥ 0
Exchange Rate	≤ 0	≤ 0	≤ 0	≥ 0	≥ 0	≥ 0	≥ 0

The first step in the sign restrictions method is to estimate the reduced form VAR model as given by equation 3.2. The lag length is determined by Akaike information criterion (AIC) and we set the lag at two for each country in our study.

5.1 Data and Restrictions

We consider countries in different stages of transformation, structure and under various policy regimes, so some of our restrictions may be rarely supported by the data. Therefore, our first

[1] The change in notation originates from the data definition, as in our notation, the increase in the real exchange rate q_t means loss of competitiveness.

exercise is focused on analysis of the support of our restrictions on shocks. To run this analysis, we identify 7 models for each country. Each of these models is very simple and identifies only one specific shock as given by the restrictions in Table 2.

Table 3: Numbers of Draws: Summary

	Countries									
Shock	CZ	SK	HU	PL	EE	LT	LV	RO	BG	SI
S. Supply	17	12	28	20	10	15	17	22	32	11
S. Demand	10	11	15	12	13	11	15	12	12	6
S. Policy	17	17	27	46	13	30	20	35	21	12
A. Supply	69	401	42	41	94	130	119	75	101	379
A. Demand	160	130	166	98	228	380	182	237	78	416
A. Policy	415	850	168	69	2938	504	261	338	8683	3778
Ex. Rate	265	319	127	102	5273	485	179	90	10915	2409

In our search for shocks, we impose restrictions in the first period, while we target 1000 accepted parameterizations. By use of the total number of draws needed, the average number of draws needed to get a successful draw is calculated. Similar to Peersman and Straub (2006), we use this number as a measure of the compatibility of data and our restrictions. Table 3 reports averages over the shocks and countries. The larger the number, the less support for the restriction is found in the data. The high average number of draws needed for Bulgaria, Estonia and Slovenia when considering the asymmetric monetary policy and real exchange rate shock signals that parameterizations compatible with shock response definition are very rare. This observation originates from the fact that for countries with fixed exchange rates, the monetary policy response avoids actions that can be rendered as asymmetric policy shocks.

Table 4: Ratio of Draws: Omitting Recent Slowdown

	Countries									
Shock	CZ	SK	HU	PL	EE	LT	LV	RO	BG	SI
S. Supply	0.7	0.5	1.0	1.6	0.8	0.5	1.5	0.9	1.0	0.8
S. Demand	0.7	0.6	0.6	0.8	0.6	0.3	0.4	1.3	0.2	0.2
S. Policy	0.6	0.5	1.8	1.4	0.4	1.0	1.3	2.1	1.7	0.3
A. Supply	1.8	4.5	0.4	1.1	2.1	2.5	2.7	1.2	1.6	6.9
A. Demand	1.4	2.8	0.8	1.0	1.2	4.5	0.6	0.3	0.7	2.0
A. Policy	0.9	1.2	0.2	0.3	1.8	0.7	1.5	0.7	1.9	4.8
Ex. Rate	1.2	1.9	0.8	0.2	2.3	4.9	0.6	0.2	1.2	3.1

It might be argued that the recent recession could amplify structural differences between the countries, thus it will be easier to find parameterizations compatible with responses to asymmetric shocks. As a robustness check, we shortened our sample by omitting data after the third quarter of 2008. Table 4 presents the results of this robustness check as a ratio of the average number of draws needed in the full sample to the average number of draws needed in the short sample. In this relative metric, if the ratio is close to unity, the restriction support was not affected by the crisis and the recession. If the ratio is greater than unity, the restriction is less compatible with data over the pre-crisis period. A ratio smaller than unity indicates that the supporting parameterization for such a restriction is easier to find over the pre-crisis period.

The simple average ratio for symmetric shocks is 0.9. This means that the number of draws needed to test are similar for the symmetric shocks in full and short data set. However, values 1.8 for asymmetric indicate that the number of draws needed for the identification of asymmetric shocks decreases when the 2008–2013 period is omitted. The inclusion of the recent recession delivers more compatibility between data and our identification scheme for the asymmetric shocks. As there are only 10 out of 30 (3 shocks and 10 countries) ratios below unity, it seems easier to support our restrictions on asymmetric shocks during the recent recession.

When analyzing data support for individual asymmetric shocks, the largest ratio of draws is needed for the asymmetric supply shock. This is consistent with the situation of higher flexibility of suppliers in the countries in the study and less flexible suppliers of their trading partners. Even for countries with peg or exchange rate targeting (Bulgaria, Romania, Hungary and Latvia) we observe that it is harder to find support for asymmetric demand restriction over the pre-crisis period.

Also, to assess the effects of adoption of the Euro for Estonia, Slovakia and Slovenia, we cut the sample at the Euro adoption date to exclude data covering Eurozone membership. The ratios of average parameterization draws needed are in the range of 0.9–1.1. When breaking down the ratio to individual shocks, we find that more parameterizations support restriction on asymmetric supply shock for all three countries. In our view, this originates from continuation of convergence process. As the ratio does not noticeably differ from unity in this check, the following analysis will be done on the full sample for all considered countries.

When considering the effect of sample length for the real exchange rate shock identification, Table 4 reports an average ratio of 1.6. This result suggests that parameterizations supporting restrictions on exchange shocks are more frequent when the underlying VAR model is estimated on the full data set.

Low support for restrictions on asymmetric shocks for most of the countries leads us to release restrictions on individual asymmetric shocks. However, the restrictions on symmetric shocks as presented in the Table 2 ensure that none of the symmetric shocks could be confused with an asymmetric shock. Therefore, it is possible to apply identification scheme that distinguishes the symmetric shocks from asymmetric ones, even though asymmetric shocks are not explicitly restricted individually.

6. Estimation Results

Discussion in the previous section suggests that the restrictions on the asymmetric responses are rarely supported by the data; and the model with restrictions on individual asymmetric shocks is hard to identify. Yet, this does not necessary imply that the shocks causing asymmetric responses have only minor impact. Therefore in the following section we employ a model where asymmetric shocks are not identified individually, but remain as ’other shocks’ in the residuals. With this model we study impulse responses and variance decomposition. We also address the relative importance of symmetric and asymmetric shocks as they contribute to each country’s business cycle, where asymmetric shocks are identified as residuals. We aware of the fact, that in addition to asymmetric shocks, the residuals may also contain noise and potential data errors. This could potentially lead to overestimation of the importance of asymmetries. Therefore, we take our estimates with caution and treat them as indicative rather than solid proved results. As in Peersman (2011), we conduct historical decomposition of the contribution of shocks to the business cycle, with the focus on each symmetric and asymmetric shock as a group of ’other shocks’.

As we aggregate asymmetric shocks, the number of individual restrictions is reduced, as described in Table 5. It resembles Table 2, but without the implicit restrictions on asymmetric shocks. However, the set of restrictions kept distinguishes each symmetric shock from any of the asymmetric shocks as restricted in the Table 2. All the restrictions are applied to responses in the first period only. The asymmetric shocks mentioned in the previous identification schemes are not individually identified and in the following analysis are referred to as ’Asymmetric shocks’.

Table 5: Baseline Model Identification Scheme

Variable Structural Shock	y_t	p_t	i_t	y_t^*	p_t^*	i_t^*	q_t
Symmetric Supply	≥ 0	≤ 0		≥ 0	≤ 0		
Symmetric Demand	≥ 0	≥ 0	≥ 0	≥ 0	≥ 0	≥ 0	
Symmetric Monetary Policy	≤ 0	≤ 0	≥ 0	≤ 0	≤ 0	≥ 0	
Exchange Rate	≤ 0	≤ 0		≥ 0		≥ 0	≥ 0

With the set of restrictions presented in Table 5, we collect the parameterizations of the structural VAR models and use the median criterion to select a representative model. Further, we present the impulse response analysis and examine sources of volatility by variance decomposition. This also allows discussion of the relative importance of the symmetric and asymmetric shocks. Finally, we are able to identify their historical contributions to the business cycle.

6.1 Impulse Responses

Impulse responses for individual countries are reported in Figures 4–13 as percentage deviations from the steady state of a variable - its trend value. As the asymmetric shocks are not identified individually, only the responses to symmetric and real exchange rate shocks are presented. The countries in the study are small open economies, so our presentation focuses on the domestic variables. Presented bands represent 90 and 95 percent confidence intervals for responses.

Generally, in response to a symmetric supply shock, a persistent increase in domestic output can be observed for all countries. Domestic inflation is restricted to decline in the first period, though it reverts rather quickly. The policy response is not restricted, so it varies across countries. However, patterns are observed as monetary policy eases in Vysegrad countries (Czech Republic, Hungary, Poland and Slovakia), tightens in Bulgaria, Romania, and Lithuania, and tightens a little in Estonia and Latvia. Slovenia responses with the tightening in the next period. As the policy eases for inflation targeting countries, the initial response of the exchange rate is depreciation, however as further output growth continues, appreciation occurs. Generally, real exchange rate depreciation follows symmetric supply shock, meaning that export oriented countries profit from lower prices and their export is cheaper.

In response to the symmetric demand shock, output, prices, and interest rates rise. Depending on the strength of monetary policy response, the positive response of output and inflation is eliminated. After the initial periods of tightened policy, inflation and output start to contract. Then the policy is eased to restore the equilibrium. For all countries, except Lithuania and Romania, the exchange rate appreciates in response to initial tightening of the monetary policy. For Lithuania a delayed exchange rate appreciation is observed and can be explained by the lagging nature of the currency board. The impulse responses presented suggest that there are differences across exchange rate responses to demand shock (depreciation in Romania and Latvia). These differences could be driven by monetary policy regimes or could be structural, but the prevailing appreciation is consistent with the growth of net exports of the countries in the study.

Romania's response to symmetric demand shock is large and persistent depreciation of the real exchange rate. Despite the competitiveness increase, Romania experiences the largest and longest decline in output of all countries in the study. We believe that this is due to structural problems in its economy and its monetary policy as regards managing the exchange rate. A conflict may exist between exchange rate and inflation rate targeting, as one can see monetary policy tightening to fight the inflation, which stays long above the equilibrium, partially due to exchange rate fall.

Symmetric monetary policy tightening is restricted to reduce output and inflation. Exchange rates depreciate for most of the countries, with the exception of Latvia, where it rises first and falls after few periods. This response suggests the presence of asymmetries in transmission channels, when both domestic and foreign economies raise interest rates while domestic monetary authority avoids appreciation. This prevents too large slowdown of output growth and fosters recovery of price level dynamics.

Restrictions on the exchange rate appreciation shock require reduction of domestic output and prices, increasing foreign output and foreign interest rate. However, in the following periods output rises very quickly above the steady state (except for Hungary), as does inflation, despite mostly tightening responses of domestic monetary policy.

To sum up, the region is represented by countries with rather heterogeneous economic structure and monetary policy regimes. Some similarities can be found within groups (Vysegrad countries and Baltic countries). In the following section, we analyze the differences in contribution of shocks to economic volatility and historical decomposition of shocks.

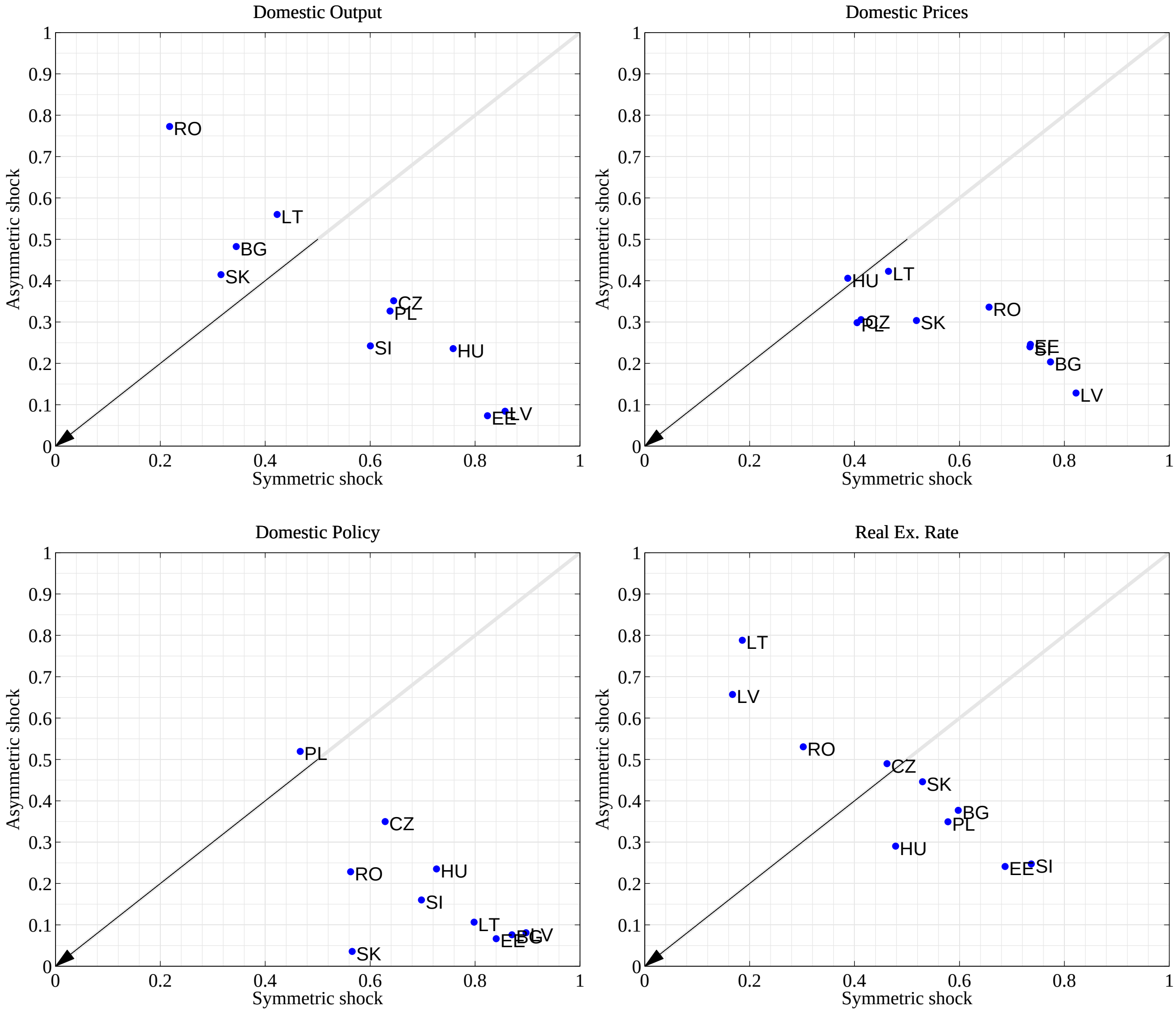
6.2 Relative Importance of Symmetric and Asymmetric Shocks

The major concerns of the optimal currency area literature, when assessing application of the single stance of the monetary policy, are the similarities of business cycles of the participating countries. The synchronization of a some degree of shocks and cycles is required to have a single stance of monetary policy, that is acceptable for the individual countries. As our shocks are defined via their impact on the economy irrespective their common or idiosyncratic origin, the assessment of the relative importance of symmetric with respect to asymmetric shocks provides guidelines on costs of dissimilarities present.

As the relative importance is varying over the periods after shocks, we consider it a from short run and a business cycle perspective. The average contribution of symmetric and asymmetric shocks for the model closest to median over the first 6 periods describes a short run and is presented in Figure 2. The relative importance for business cycle is assessed by taking the average from the sixth to the thirty second period after shock and the is presented in Figure 2. The detailed evaluation of the shock contributions is presented in Figures 14–23. As we study small open economies, each figure shows decomposition only for the domestic variables.

Aggregating the contributions of symmetric and asymmetric shocks allows us to assess their relative importance. For countries with relatively high contribution of symmetric shocks, synchronization of the business cycles with its trade partners is high. So, the costs for the small open economy to adopt common monetary policy with its trading partners are considered to be rather small. However, if asymmetric shocks have relatively high contribution, the required response of the monetary policy

Figure 2: Short Run: Symmetric vs Asymmetric Shock Contributions

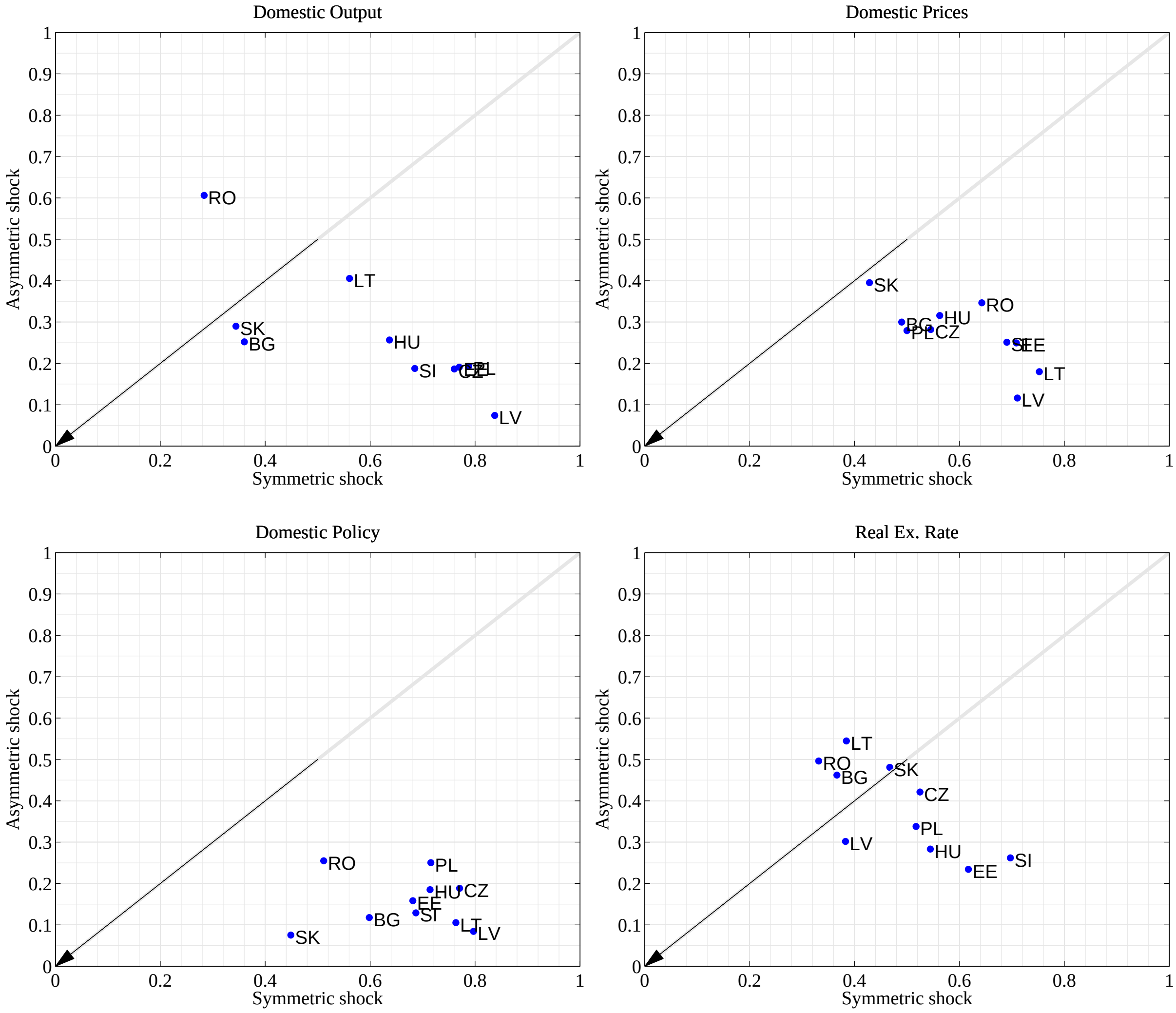


is the opposite in both countries and giving up an independent monetary policy can be very costly. As a result, to form a currency union, it is important that the contribution of asymmetric shocks to the business cycle is small.

Countries with the substantial contribution of asymmetric shocks to output volatility in the short-run are Romania, Lithuania, Slovakia and Bulgaria, where it can reach up to 80 percent in the initial period (see Figure 22 for Bulgaria). The contribution of asymmetric shocks to output volatility is also high in the long-run for these countries, where contributions are in 20–60 percent interval. For the rest of the countries in the study, the long-run contribution of the asymmetric shocks is below 20 percent.

The group of the countries with the strongest short-run contribution of asymmetric shocks to domestic prices volatility includes Czech Republic, Hungary, Poland, Lithuania, Romania and Slovakia, where the contributions range from 25 to 40 percent. As our sample includes transition countries, there is high percentage of administered prices present in these economies. The adjustment of these prices often follows schemes that are not correlated with the business cycles of other countries, therefore it can result in asymmetries.

Figure 3: Business Cycle: Symmetric vs Asymmetric Shock Contributions



Countries with prevailing contribution of asymmetric over symmetric shocks to real exchange rate in the long-run are Bulgaria, Lithuania, Romania and Slovakia. If we consider short-run contributions, Czech Republic and Latvia join this group, while the contribution of asymmetric shocks for Bulgaria drops. Most of the relatively high contribution (almost 80 percent) for Latvia can be explained by the choice of the exchange rate peg as policy, with the prevailing regime for this group being either exchange rate targeting or exchange rate peg. The substantial contribution of asymmetric shocks is consistent with the shock absorbing nature of the real exchange rate.

Countries with low contribution of asymmetric shocks to domestic prices include Bulgaria, Estonia and Latvia. For these countries, symmetric shocks account for about 80 percent of the volatility of prices. Variance decompositions for domestic output, prices and policy, presented in Figures 22, 18 and 20, is dominated by the contribution of symmetric shocks at almost all horizons. This group of countries is also characterized by peg and fixation of their currencies to Euro. This choice of monetary policy sets up a strong link between domestic and foreign prices and interest rates, thus resulting in limitation of the presence of asymmetric shocks.

Variance decomposition shows a large influence of asymmetric shocks on specific groups of considered economies. Even though asymmetric responses are not frequent in the data, together they account for a significant portion of output and price volatility. Due to their relative importance to volatilities of considered variables, the frequency of occurrence has to be compensated by their amplitude. The presence of substantial asymmetry originates from asymmetries across the considered countries in terms of productivity, monetary and exchange rate policies. There are striking differences in relative contribution of the asymmetric shocks across countries, as their contribution to output volatility varies from 10 to 80 percent.

6.3 Role of the Real Exchange Rate

In theory, the role of the real exchange rate is to act as a mechanism which reacts to structural shocks and helps to stabilize output and inflation variability. However, there is empirical evidence suggesting that real exchange rates are very volatile, which further fuels macroeconomic volatility and causes economic disturbances. Therefore, the crucial question is what portion of exchange rate fluctuations originates from the idiosyncratic real exchange rate shocks and what is the influence of these shocks on volatility of output, prices and monetary policy. Assessing how much volatility the real exchange rate generates or absorbs is not a straightforward exercise and could be subject to debate. In this paper we pursue the approach developed in the literature (Peersman, 2011; Clarida and Gali, 1994; Farrant and Peersman, 2006), where studies consider what fraction of the exchange rate volatility is driven by its own shock. The intuition behind this approach is the following. If exchange rate volatility is driven mostly by, for example, the supply shock, it is a sign that the exchange rate largely reacts to the supply shock. This could be interpreted as absorbing the supply shock. If, however, the exchange rate is driven mostly by the idiosyncratic shock, it could be interpreted as having little role as a shock absorber. Another question related to the analysis is what to consider a 'large' reaction to a shock. Generally in the literature, and in line with common sense, less than 10 percent is not considered to be important source of volatility, while more than 20 percent is already an important source of volatility.[2]

Figures 14–23 present decomposition of the real exchange rate, highlighting the contribution of real exchange rate shock. If this contribution is high, the exchange rate absorbs little volatility from remaining structural shocks and thus does not serve as an important stabilization mechanism. However, if one aims to judge whether the real exchange rate is itself a source of volatility, its impact for volatility of output, prices or monetary policy is more important. If the contribution of the real exchange rate is low, idiosyncratic exchange rate fluctuations are not harmful to the rest of economy.

The short run contribution of the idiosyncratic real exchange rate shock to real exchange rate volatility ranges from a tiny 1 percent in the case of Slovenia to approximately 5 percent for Bulgaria, Czech Republic and Slovakia, and up to 20 percent for Hungary and Latvia. This is far below the 45 percent of Sterling-Euro fluctuations explained by idiosyncratic shock in the short-run as identified by Peersman (2011). In the long-run, the idiosyncratic shock fuels Latvia's real exchange rate volatility by 30 percent. Meanwhile, most of the countries form two distinct groups, one with a contribution approximately of 15 percent and the other at 5 percent. The latter values are in line with findings by Clarida and Gali (1994) and Farrant and Peersman (2006). On the other hand, even contributions of exchange rate shocks in the former group are still remarkably lower than the

[2] Clarida and Gali (1994) call 35-41 percent of exchange rate variance explained by nominal shock a 'substantial amount', Peersman (2011) considers more than 30 percent 'significant'. On the other hand, Uhlig (2005) calls 5-15 percent variation explained a 'small' fraction.

results obtained by Artis and Ehrmann (2000) for Denmark, Germany and United Kingdom, where contributions range from 50 to 90 percent.

Works like Clarida and Gali (1994) and Eichenbaum and Evans (1995) that attempt to identify the contribution of various shocks to the real exchange rate often find that monetary policy shocks are unimportant. However, our results suggest that the symmetric monetary policy shocks deliver an important part of the real exchange rate volatility for Czech Republic, Hungary, Poland and Slovenia. Thus, we can support the conclusion reached by Rogers (1999) that monetary policy shocks matter and that the focus on monetary shocks in the recent dynamic general equilibrium literature is empirically well-founded.

When considering the transition of real exchange rate shocks to domestic output in the short-run, countries can be split into three groups. Slovakia's output is significantly driven by exchange rate shock as its contribution reaches up to 25 percent. For Bulgaria, Estonia and Slovenia the short-run contribution is on average 12 percent, while for the rest of the countries there is either no effect (Czech Republic) or effects are less than 5 percent. In the long-run, a high contribution of 35 percent is present for Bulgaria and Slovakia, somewhat high contribution of approximately 15 percent is present for Slovenia, while the rest of the countries are characterized by a contribution lower than 10 percent. Most countries in the study exhibit an interesting pattern; in which the contribution of the exchange rate shock is almost nil or very low in the initial periods after the shock, while over the time it starts to increase. This behavior reflects the speed of the exchange rate to output pass-through.

In the short-run, exchange rate shock substantially contributes to the volatility of domestic prices in Czech Republic, Poland, Hungary and Slovakia (15–30 percent). There is another distinct group including Bulgaria, Estonia, Latvia, Romania and Slovenia, where the short-run pass through is low, below 5 percent. Poland is characterized by largest long-run contribution of real exchange rate shock to domestic prices (30 percent). The group close to the average contribution of 15 percent is dominated by inflation targeting countries – Czech Republic, Slovakia, Latvia and Hungary. Surprisingly, Bulgaria also belongs in this group, while the countries with pegged exchange rate or early Euro adopters like Estonia, Latvia or Slovenia are in the group with the long-run contribution below 8 percent.

The monetary policy volatility decomposition in the long-run shows an exceptionally high contribution of exchange rate shock for Slovakia, where it reaches 45 percent. Clearly, Slovakia's monetary policy is highly responsive to movements in the exchange rate. As a large effect of exchange rate shock is found for domestic output, the large contribution of exchange rate shock to domestic monetary policy originates from the use of the Taylor rule with inflation and output gap components. Czech Republic and Poland have a low (below 5 percent) monetary response to exchange rate shocks. Remaining countries evenly cover a range of contributions from 8 to 22 percent. As there are many rigidities present, the short-run contributions to volatility are lower than the long-run. However, the ordering of countries does not change much when short run effects are considered.

For most countries in the study (except Bulgaria, Poland and Slovakia) results illustrate that real exchange rate shock does not significantly contribute to volatility of the domestic variables. Generally, the most significant effect of exchange rate shock is identified for domestic prices. This is not surprising, given that most of the countries are open and small (to their foreign counterparts in the study), the movements in real exchange rate are passed into prices as these are more responsive than the output. For most of the countries the transmission of real exchange rate shock is lagged and it slowly reaches its long-term value of contribution.

When considering the potential of the real exchange rate to act as a shock absorber, attention should be paid to variance decomposition of the real exchange rate. When the contribution of shocks other than idiosyncratic shocks is large, this could be interpreted as a sign of shock absorption. Figures 14–23 show that for most of the countries real exchange volatility is attributed to mostly asymmetric shocks. Their long-term contribution is about 50 percent for Czech Republic, Slovakia, Latvia, Lithuania, Romania and Bulgaria, with short term contribution close to 100 percent for Lithuania and Latvia. For the rest of the countries in our sample, asymmetric shocks cause from 20 to 30 percent of the variation in the real exchange rate. We interpret such an impact as a sign of absorption of asymmetric shocks. Hungary, Poland and Slovenia demonstrate large impact of monetary policy shock on real exchange rate volatility, up to 40 percent. In Slovakia, Estonia and Lithuania, real exchange rate act as absorbing supply shock, accounting for up to 30-40 percent of the variance.

To conclude, in the selected countries exchange rate volatility is mostly driven is mostly driven by symmetric and asymmetric shocks, rather than by real exchange rate shocks. The low contribution of idiosyncratic shock to its variance indicates that the exchange rate does not generate much of volatility on its own, but rather responds to domestic and foreign shocks. For countries with very low impact of the exchange rate shocks on other domestic variables, this may imply that the exchange rate is not a source of volatility. At the same time, the real exchange rate volatility is fueled by shocks, not including idiosyncratic.. This finding is interpreted as shock absorbing property of the real exchange rate.

6.4 Estimation of Historical Shocks

The identification of structural shocks is often a controversial issue, so to support our choice of technique and identifying restrictions, we present results of historical shock estimation over the considered sample. As in the previous analysis, this identification is based on the closest to median model which is fitted to the data. The result of this estimation provides the overall contribution of the symmetric, asymmetric and real exchange rate shocks to the observed business cycles.[3]

Figures 24–33 show a period of economic boom preceding the most recent economic slowdown linked to the financial crisis of 2008. Results suggest that a group of countries exists where the business cycles were dominantly driven by the symmetric supply and demand shocks. This group includes Czech Republic, Poland, Estonia, Lithuania and, Latvia and these shocks explain a substantial amount of the output and prices movement and monetary policy responses.

Asymmetric and real exchange rate shocks were important for output in Romania and Slovakia as they together explain a substantial amount of the output fluctuations. The asymmetric shocks were also significantly contributing to evolution of domestic prices. However, the main driver for Romanian prices was symmetric price shock, while this is not the case in Slovakia.

In the case of Bulgaria, we identify the substantial role of the real exchange rate shocks, consistent with its currency board policy. The idiosyncratic real exchange rate shocks are also the most influential driver of domestic variables. In Bulgaria in both pre and crisis times, the exchange rate shock dominated output and prices volatility, having a declining role after 2009. A similar pattern

[3] Here, the asymmetric shocks also include effects of initial state. The general pattern for the contribution of initial state is a significant contribution in the few initial periods (start of the dataset) and negligible contribution in the recent periods. As the initial state also reflects some asymmetry in the setup we aggregate its contribution with asymmetric shocks.

is observed for Romania but with a stronger exchange rate shock influence. This is the result of the explicit exchange rate targeting in the case of Bulgaria.

As in the previous sections, we examine the role of monetary policy on output, and find ample role of the symmetric policy shock for Slovenia on domestic variables. These results are consistent with the adoption of the Euro and common monetary policy in 2007. However, such behavior is not observed for Slovakia, which also adopted the Euro.

The role of monetary policy in the Czech Republic for the evolution of output over the period 2005–2011 should also be noted. In the initial stage the symmetric policy shock contributed positively to growth. However as the output deviation became large (in 2007) the policy became restrictive. After the slowdown hit the economy (in early 2009) policy again eased and tried to support recovery. A similar pattern is observed for domestic price developments. Such patterns are also seen for domestic output in the case of Poland and Latvia. However, in the case of Latvia, the expansionary policy contribution occured with a lag, since the Latvian economy was severely hit by a slowdown in the foreign environment.

Historical analysis highlights different driving forces for the countries' business cycles. These findings are consistent with their past experience and the setting of monetary policy. Generally, the common feature of the economies under consideration is the relatively low contribution of the real exchange rate to cyclical movements. With the exception of Bulgaria and Latvia, the real exchange rate has been driven by shocks other than the idiosyncratic one. Such an outcome for the real exchange rate is consistent with its shock absorbing role.

7. Conclusion

In this paper we study the role of the real exchange rate in a number of Central and Eastern European countries vis-Ă -vis effective Eurozone. We find that the region is represented by heterogeneous countries, with the relative importance of asymmetric shocks varying from 10 to 80 percent. There are differences in terms of impulse responses to shocks. These differences originate from versatile economic structures, monetary policy and exchange rate regimes of the countries considered.

Some similarities are, however, observed. For most of the countries (except Bulgaria, Poland and Slovakia), results illustrate that real exchange rate shock does not generate significant volatility in macroeconomic variables. We interpret this as indicating that the exchange rate is not a source of additional volatility. The largest contribution of the idiosyncratic exchange rate shock is to volatility in prices. This is interpreted as countries being small open economies with tight trading links to the Eurozone. Therefore, movements in the real exchange rate are transmitted into prices, with rather small effect on output. We also find that reaction to idiosyncratic shock is lagged, reflecting the speed of exchange rate pass-through. The results of the variance decomposition also suggest that the real exchange rate acts as a shock absorber.

The results of the study are relevant for academics and policy-makers when considering a question of a common currency area. When asymmetries in response to shocks prevail, it implies that forming a currency union is not desirable. Also, if countries need to respond to a shock with the opposite monetary policy action, a common monetary policy is not optimal for them.

Another policy related question is if the real exchange rate can act as a shock absorber when the nominal exchange rate is fixed with a currency union. For the countries analyzed, the real exchange rate behavior is consistent with a shock absorbing role. We also find little evidence of a shock-generating role for the real exchange rate.

We acknowledge that our results should be taken with caution. First of all, the countries considered have data starting from the late-1990s, leaving us with only 63 quarterly observations. Also, the impact of asymmetric shocks could be biased towards larger impact, as asymmetric shocks are identified as 'the rest of the shocks' and could be contaminated with other unidentified shocks and data errors. However, we believe that our study serves to provide useful guidance for both academics and policy-makers when considering currency unions in the CEE region.

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Appendix A: Impulse Response Functions

Figure 4: Impulse Response Functions – Czech Republic

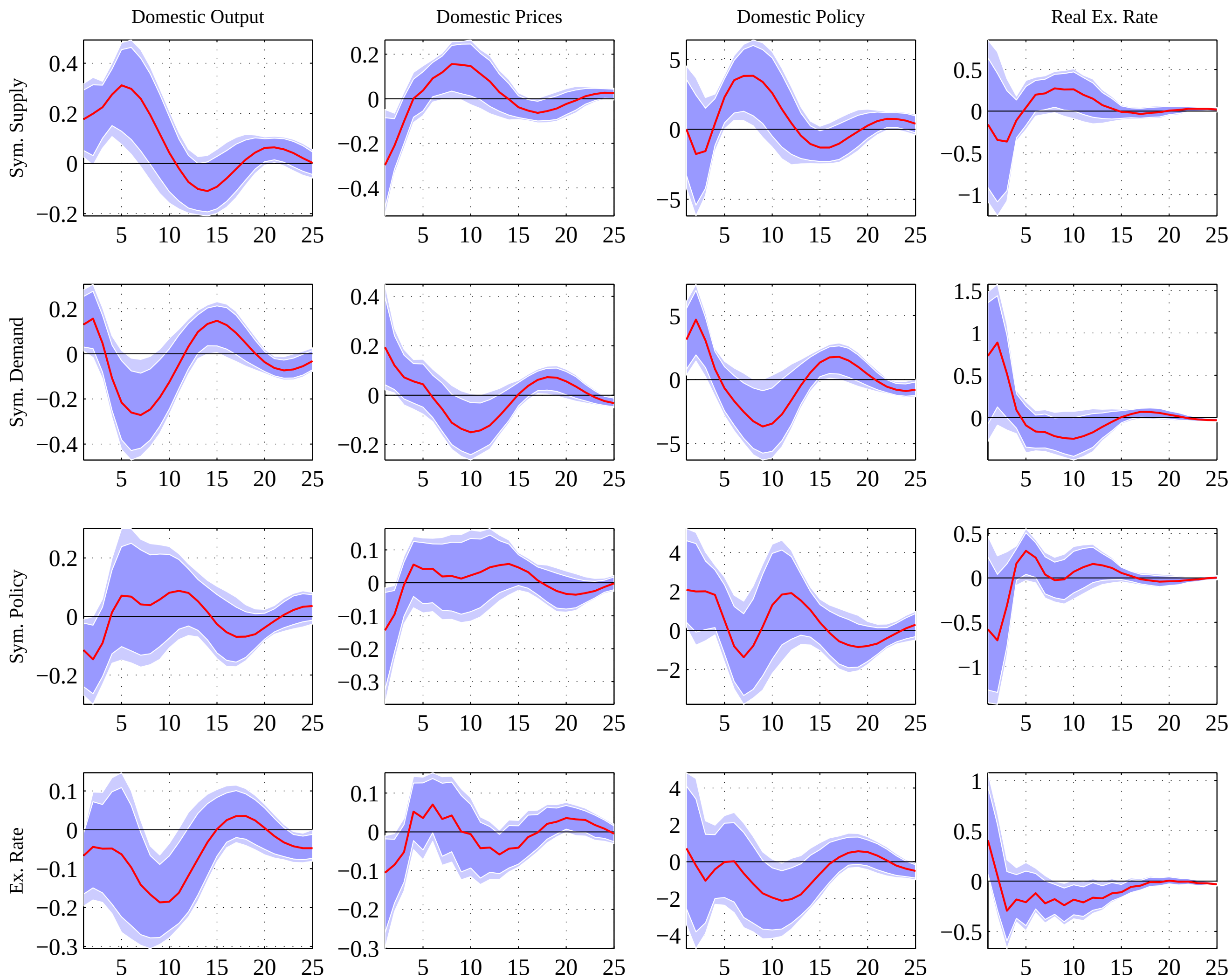


Figure 5: Impulse Response Functions – Slovakia

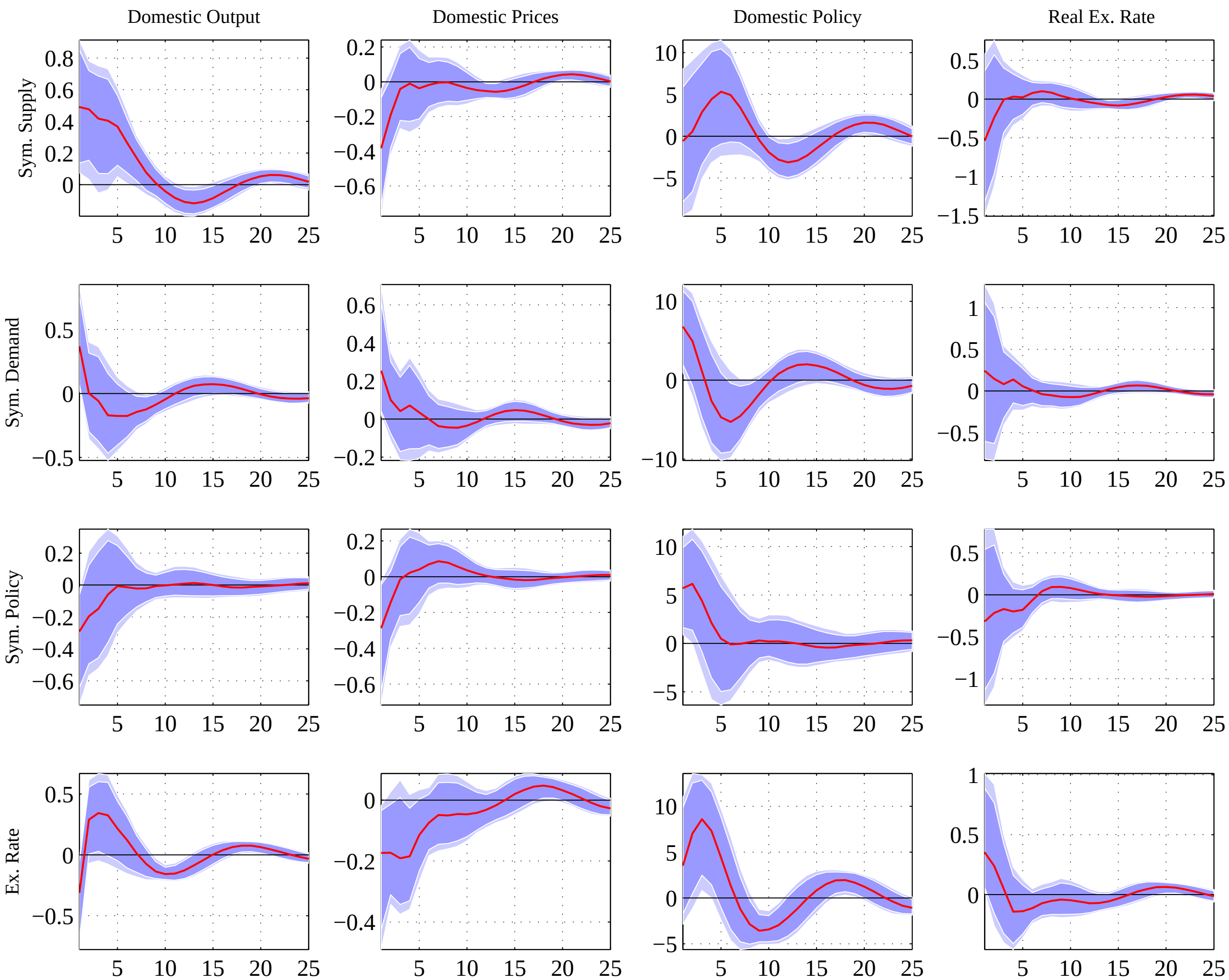


Figure 6: Impulse Response Functions – Hungary

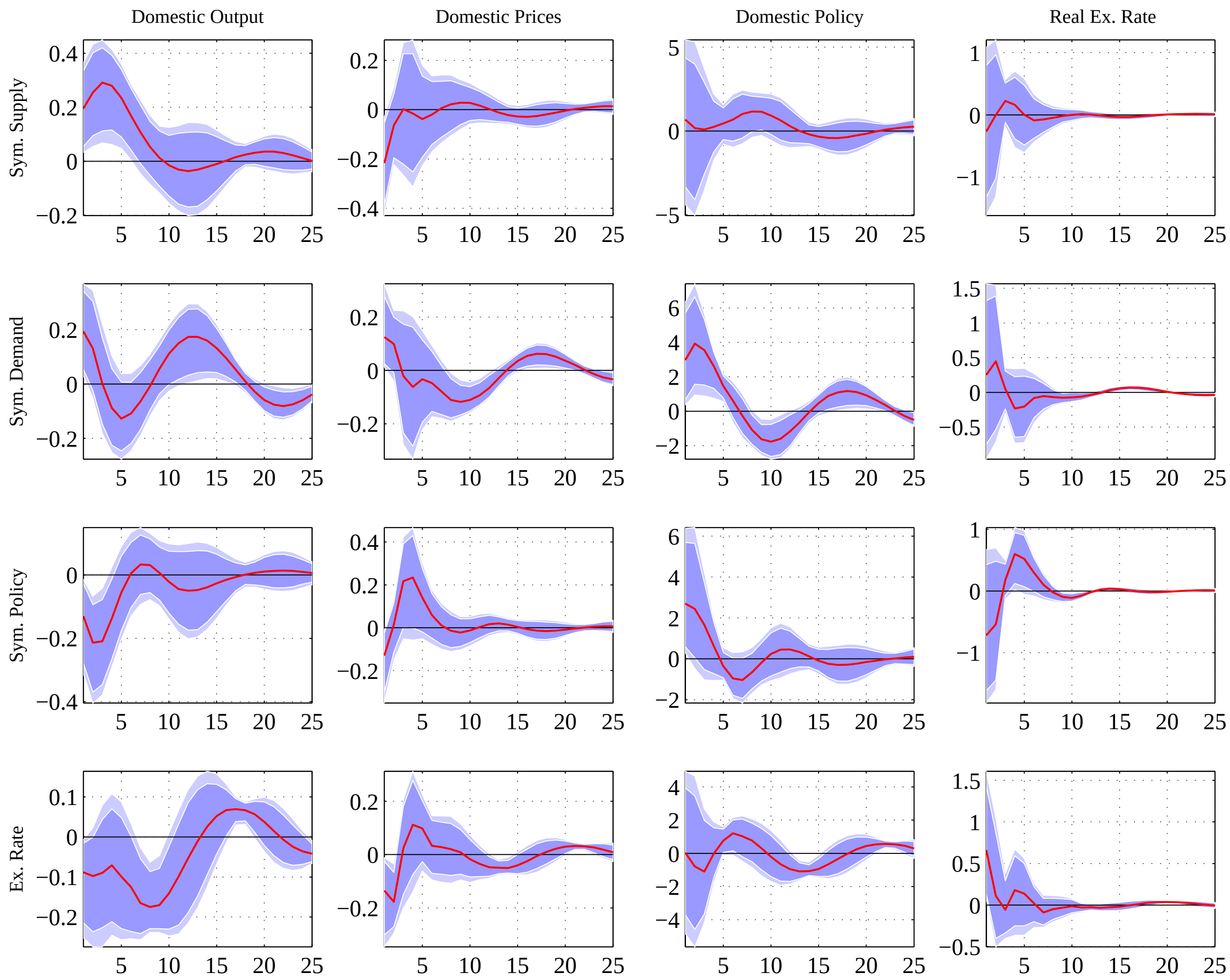


Figure 7: Impulse Response Functions – Poland

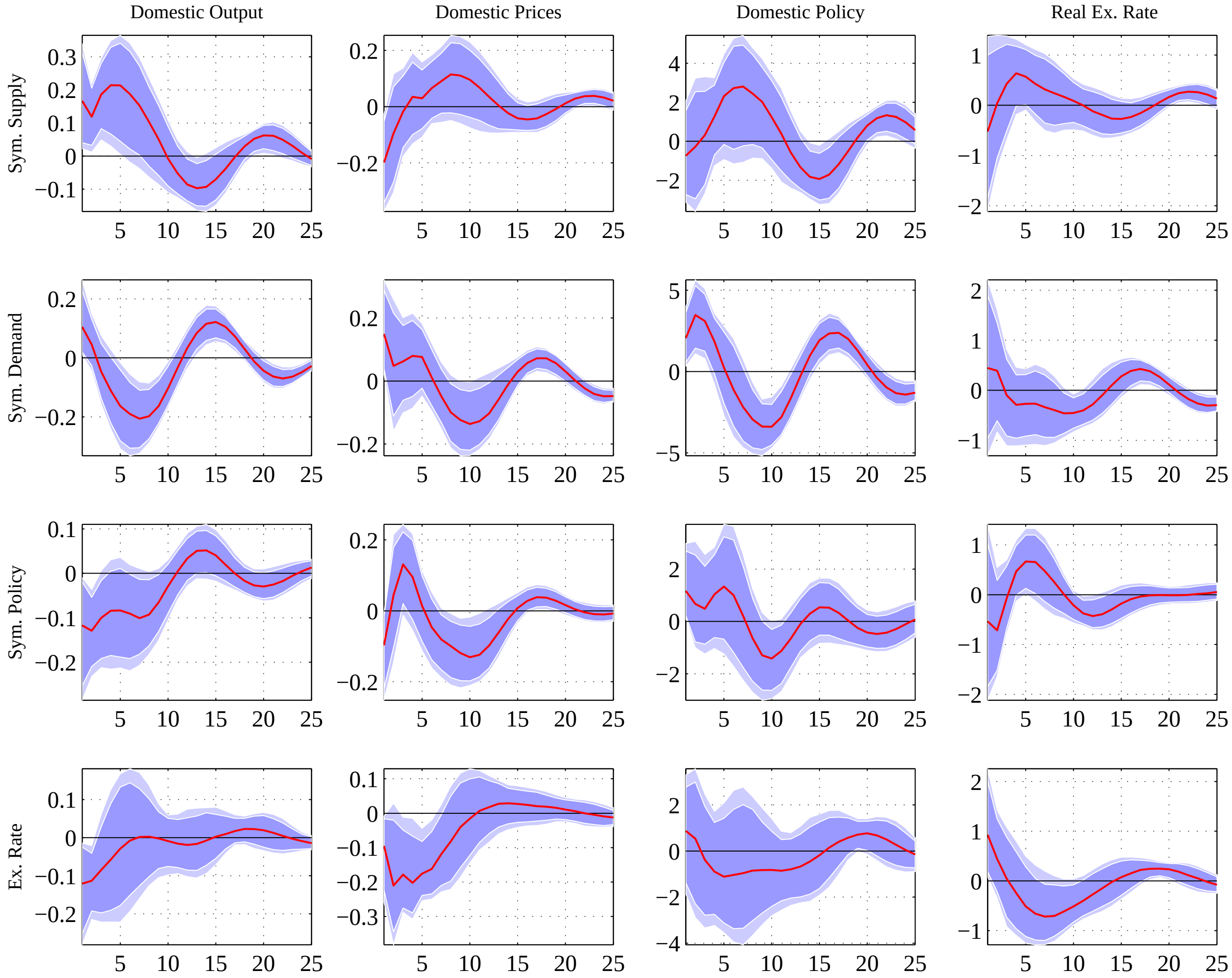


Figure 8: Impulse Response Functions – Estonia

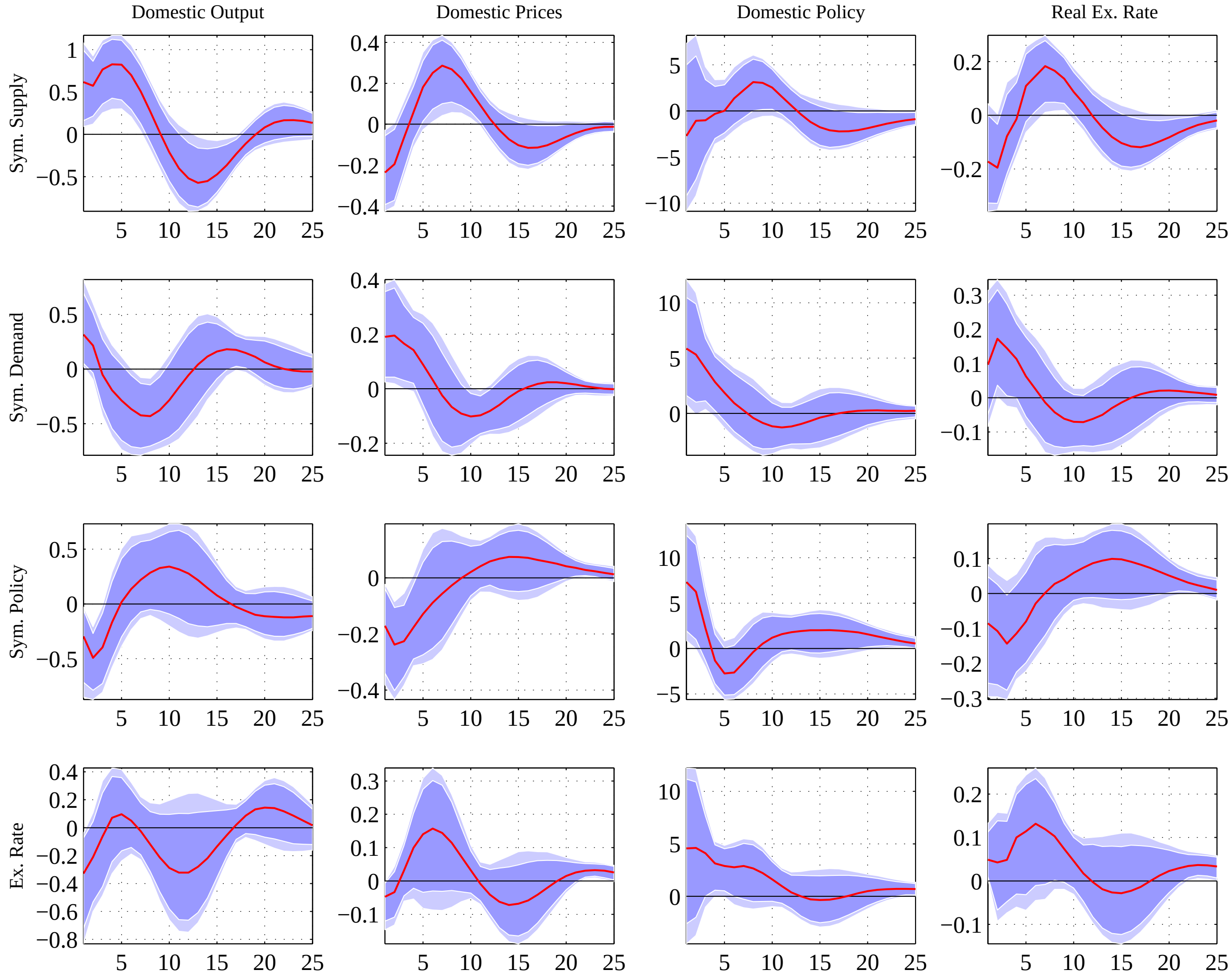


Figure 9: Impulse Response Functions – Lithuania

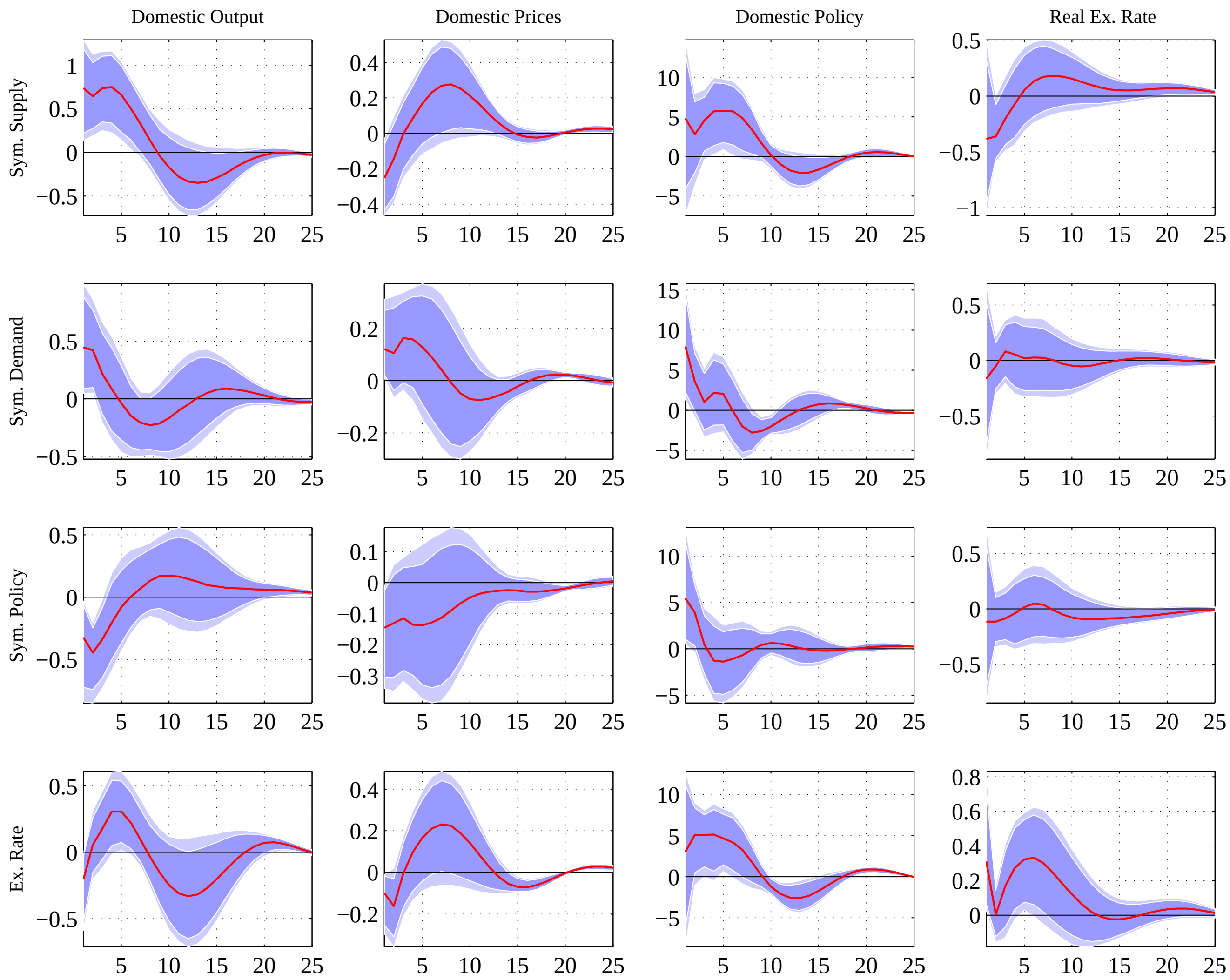


Figure 10: Impulse Response Functions – Latvia

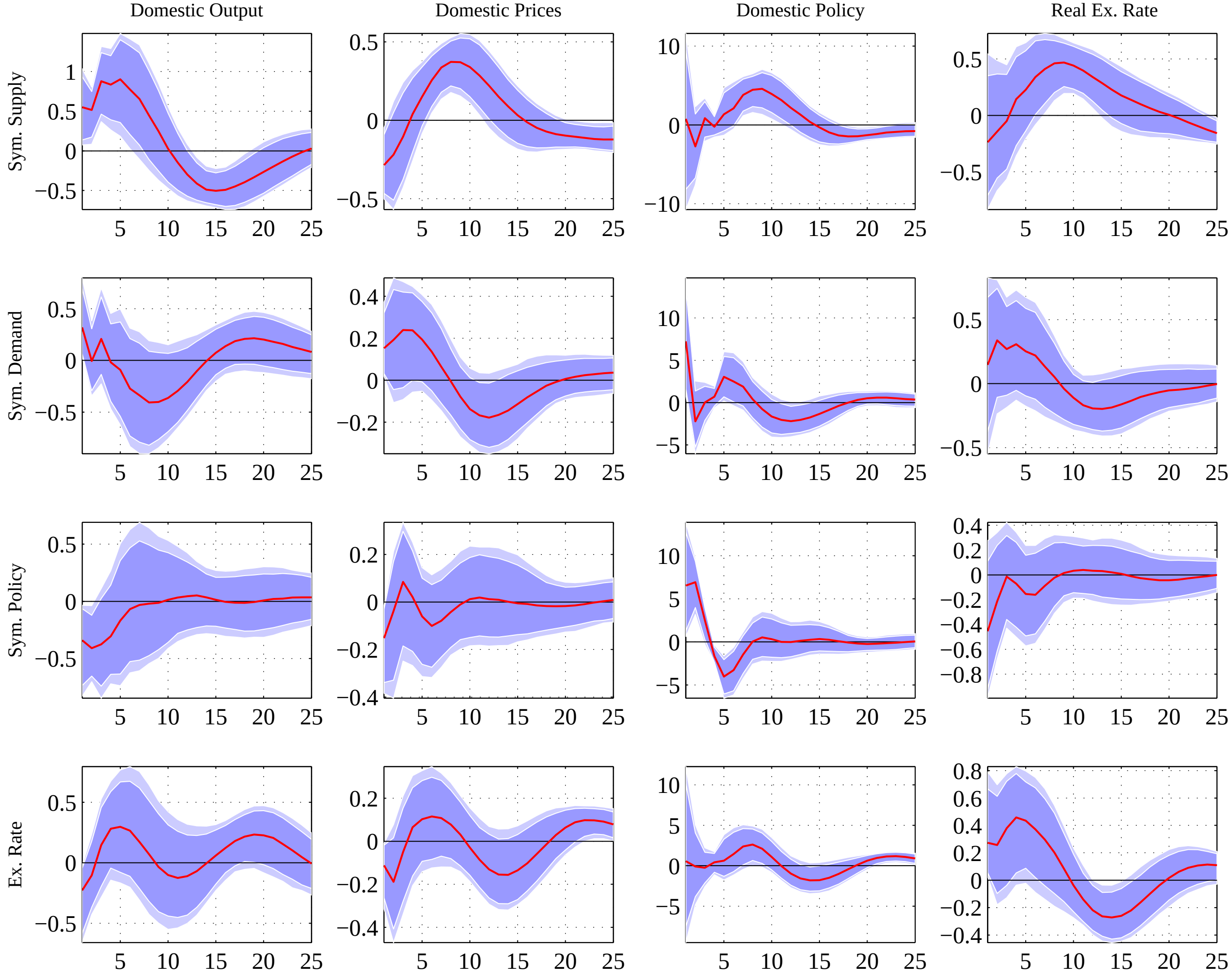


Figure 11: Impulse Response Functions – Romania

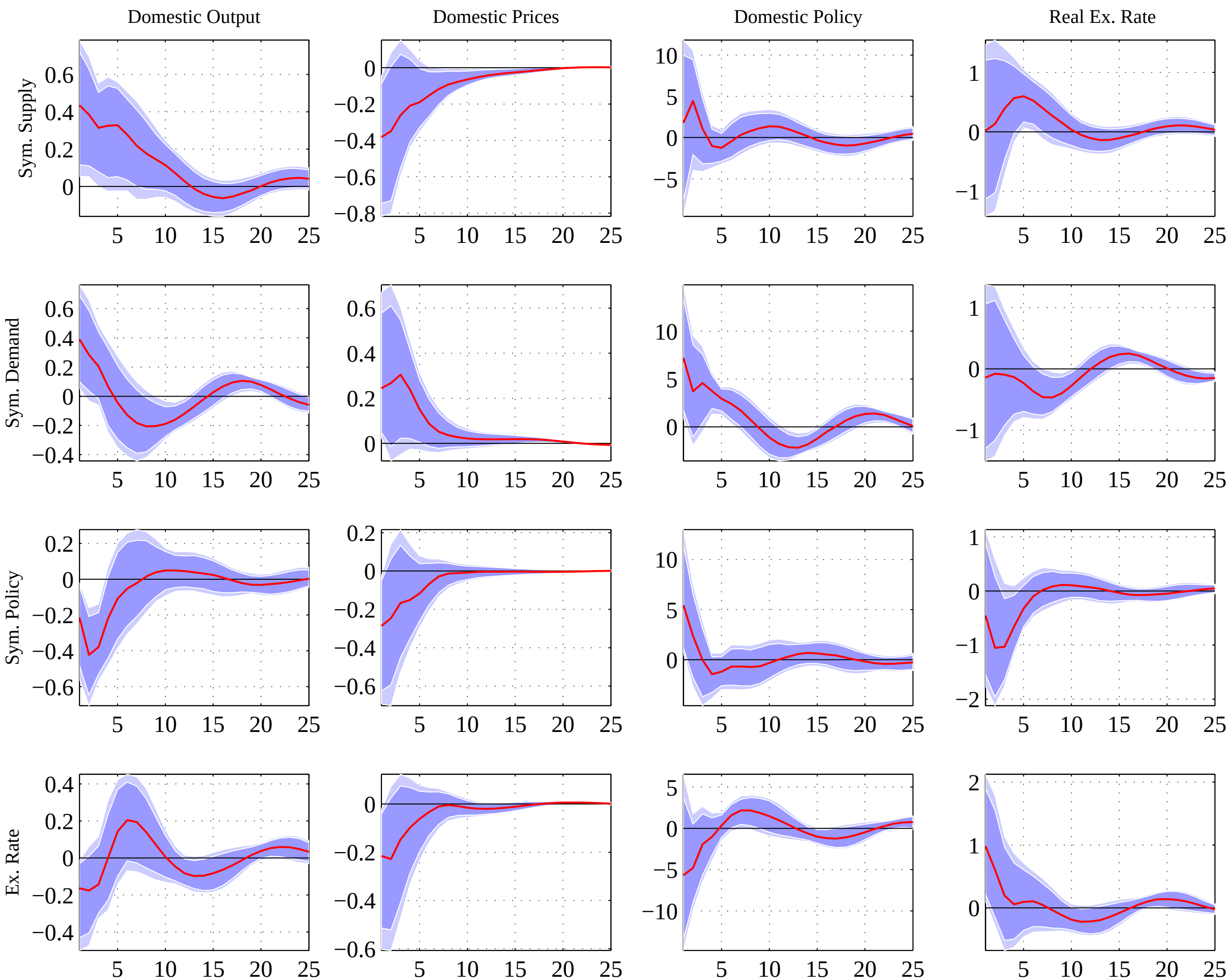


Figure 12: Impulse Response Functions – Bulgaria

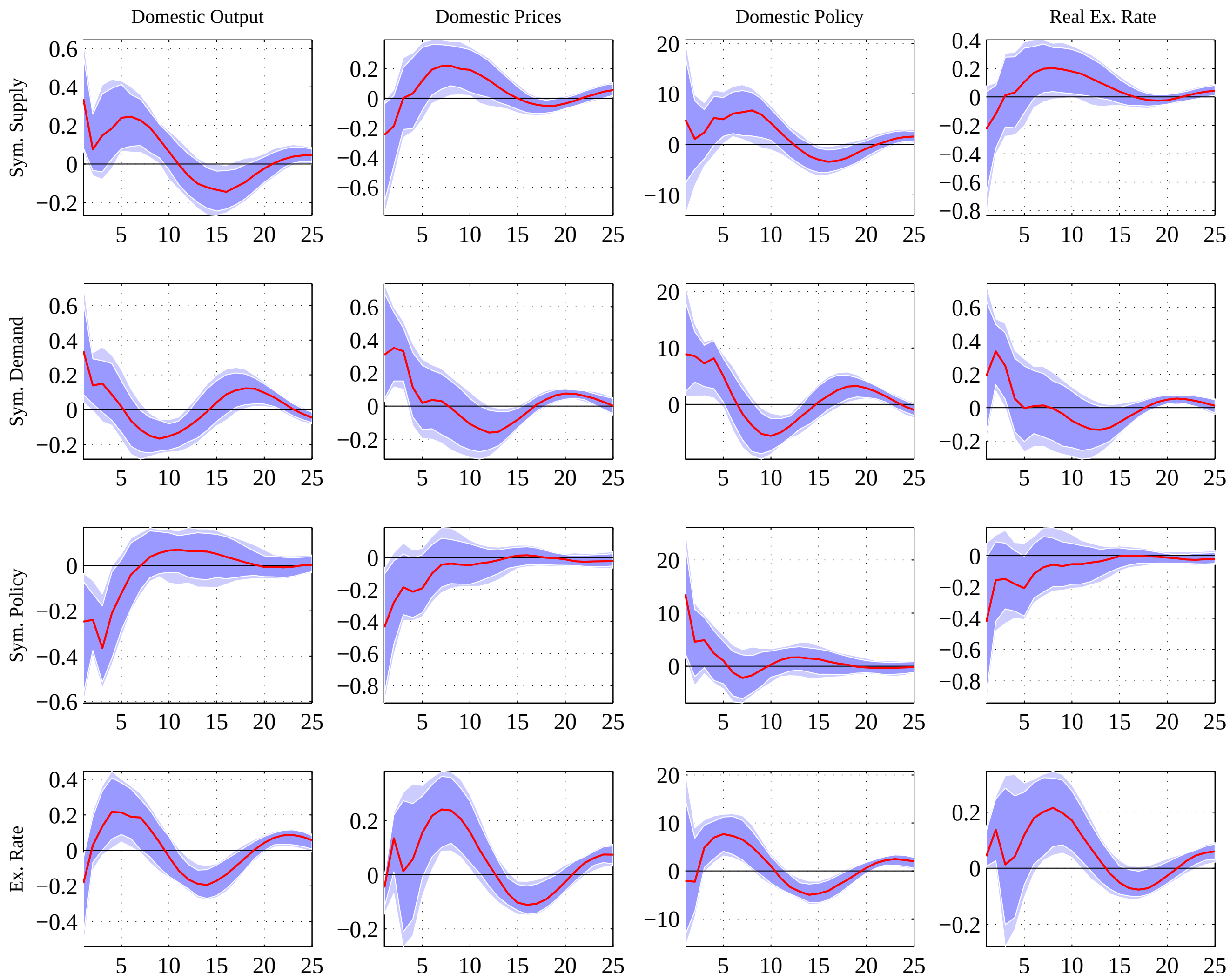
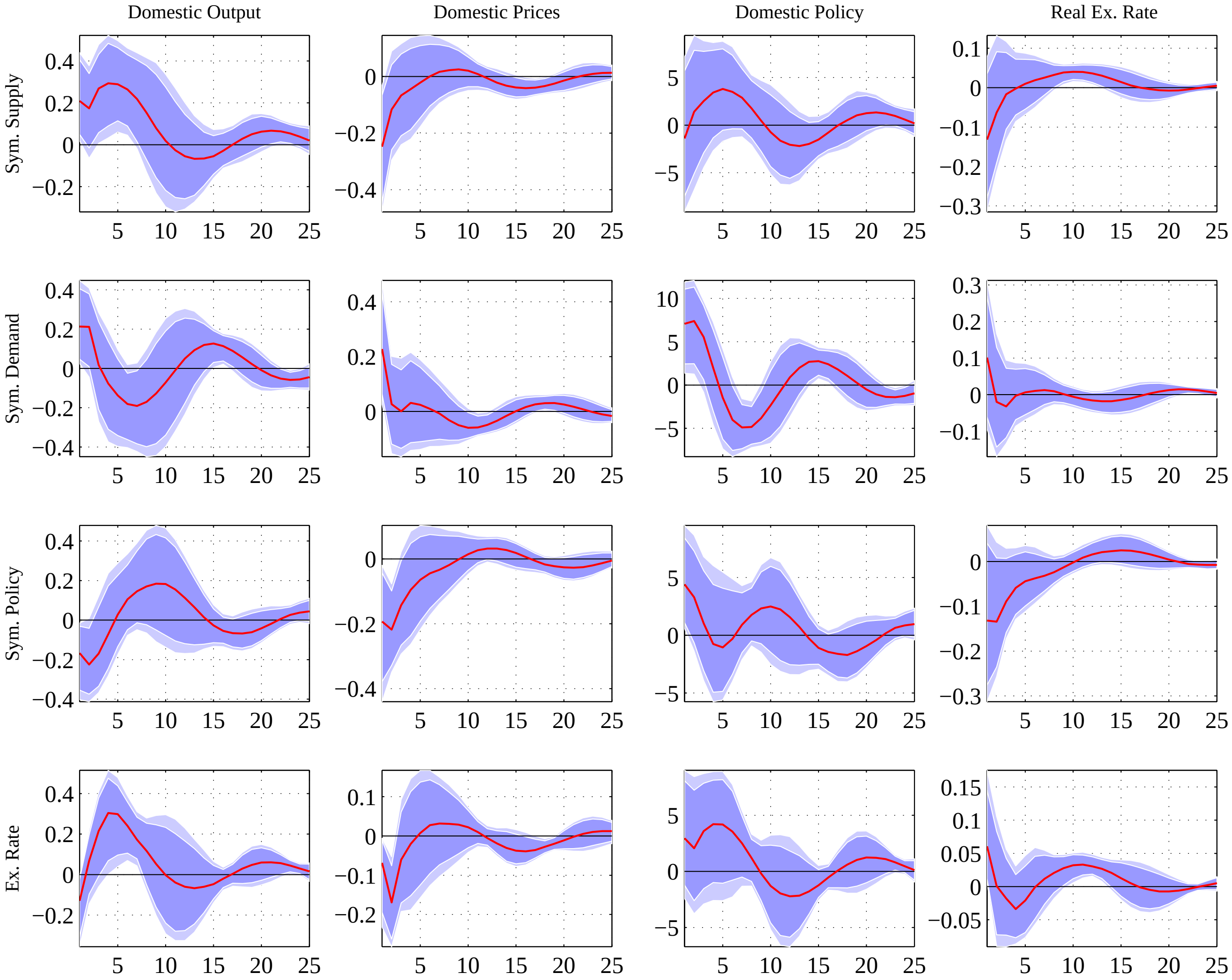


Figure 13: Impulse Response Functions – Slovenia



Appendix B: Variance Decomposition

Figure 14: Variance Decomposition: Czech Republic

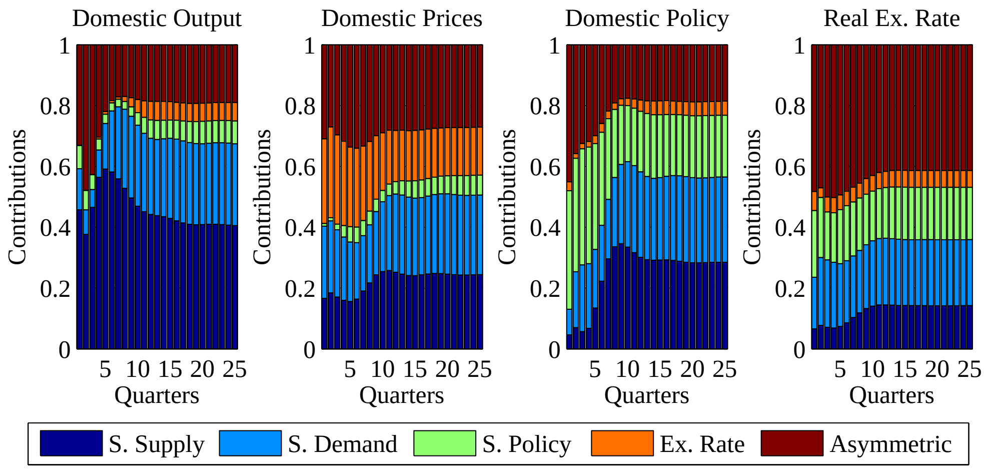


Figure 15: Variance Decomposition: Slovakia

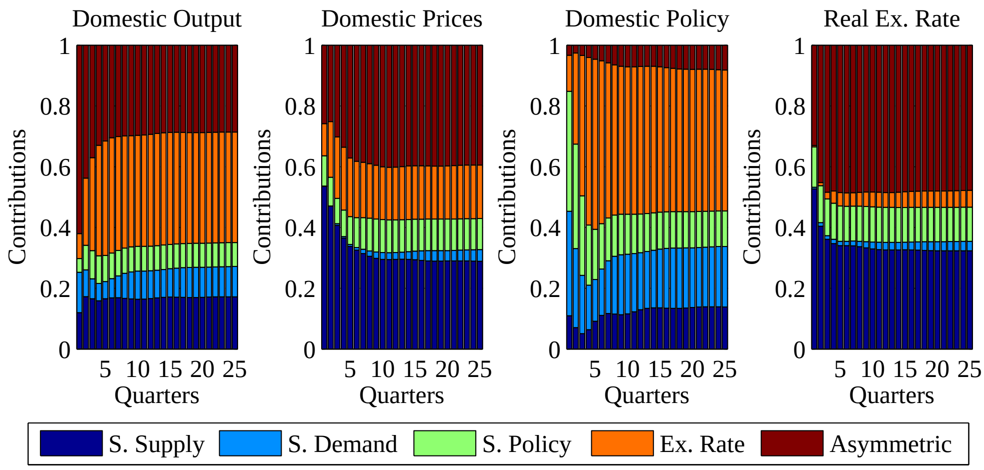


Figure 16: Variance Decomposition: Hungary

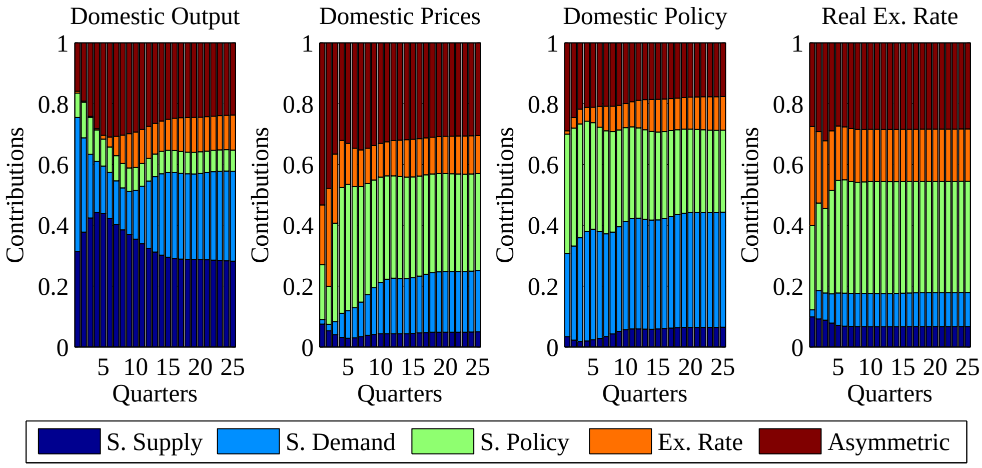


Figure 17: Variance Decomposition: Poland

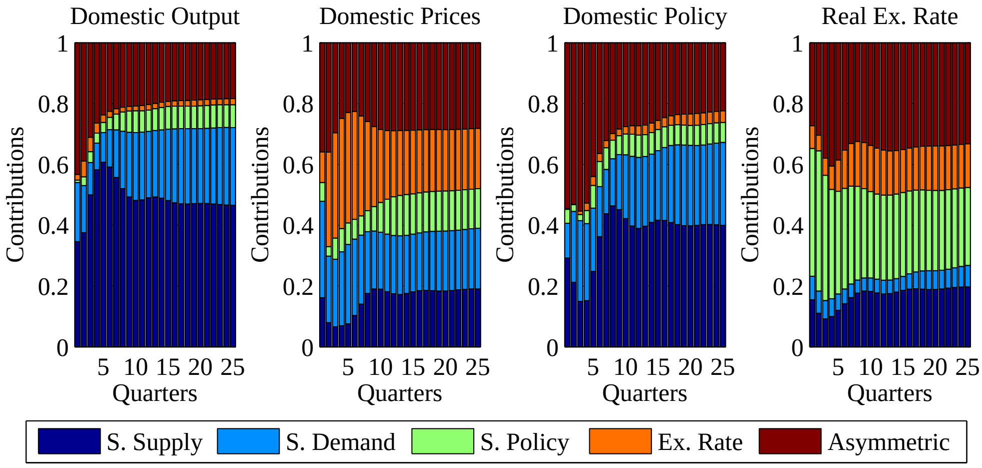


Figure 18: Variance Decomposition: Estonia

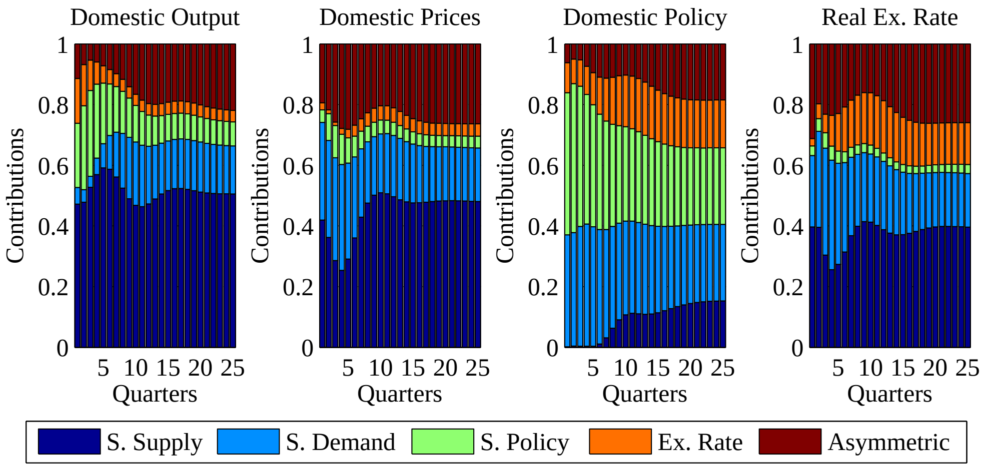


Figure 19: Variance Decomposition: Lithuania

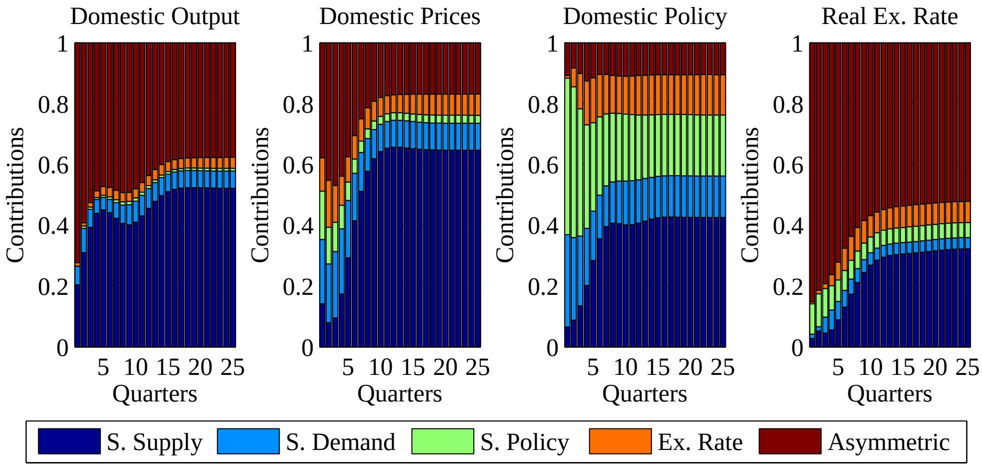


Figure 20: Variance Decomposition: Latvia

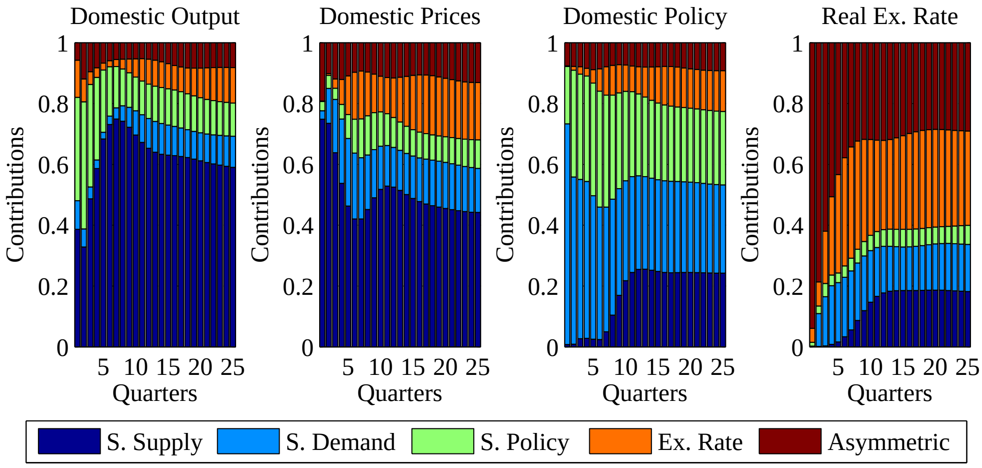


Figure 21: Variance Decomposition: Romania

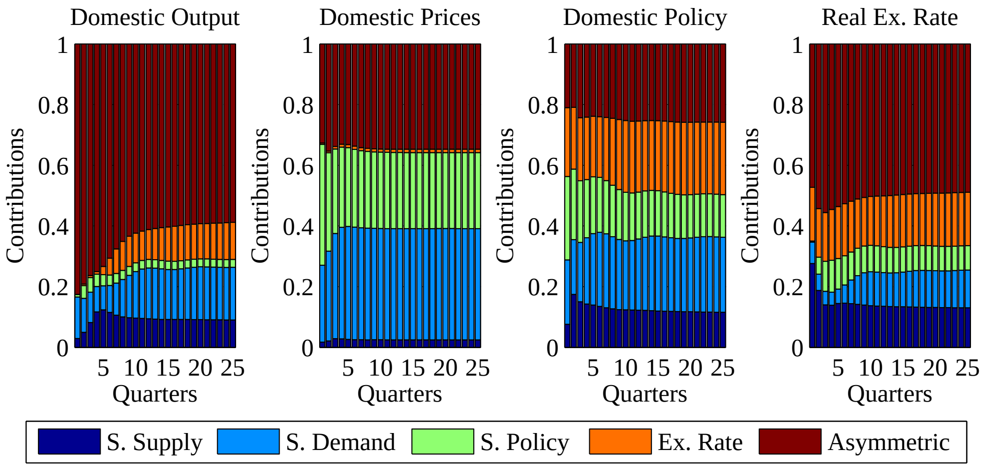


Figure 22: Variance Decomposition: Bulgaria

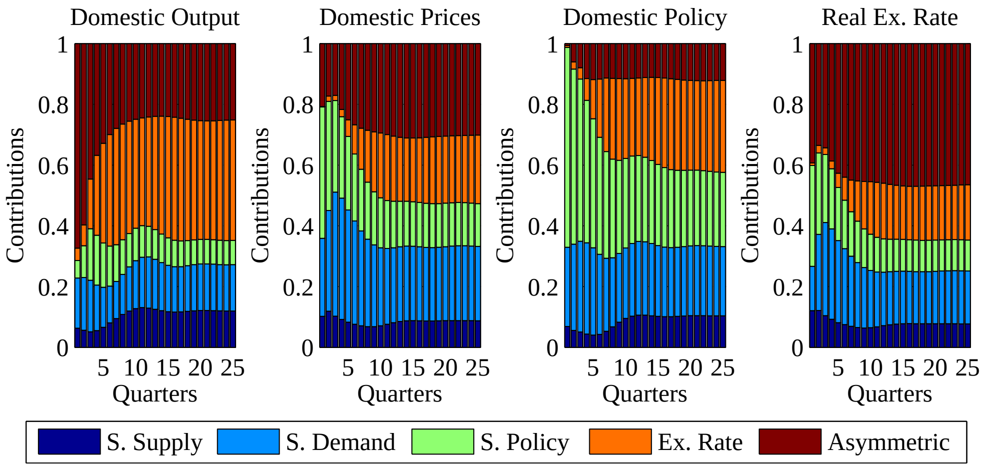
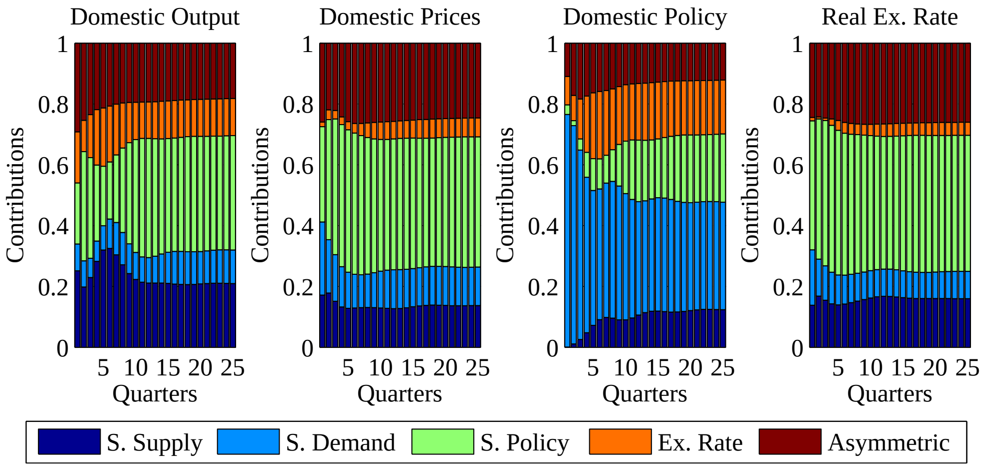


Figure 23: Variance Decomposition: Slovenia



Appendix C: Identified Shocks

Figure 24: Shocks Contributions – Czech Republic

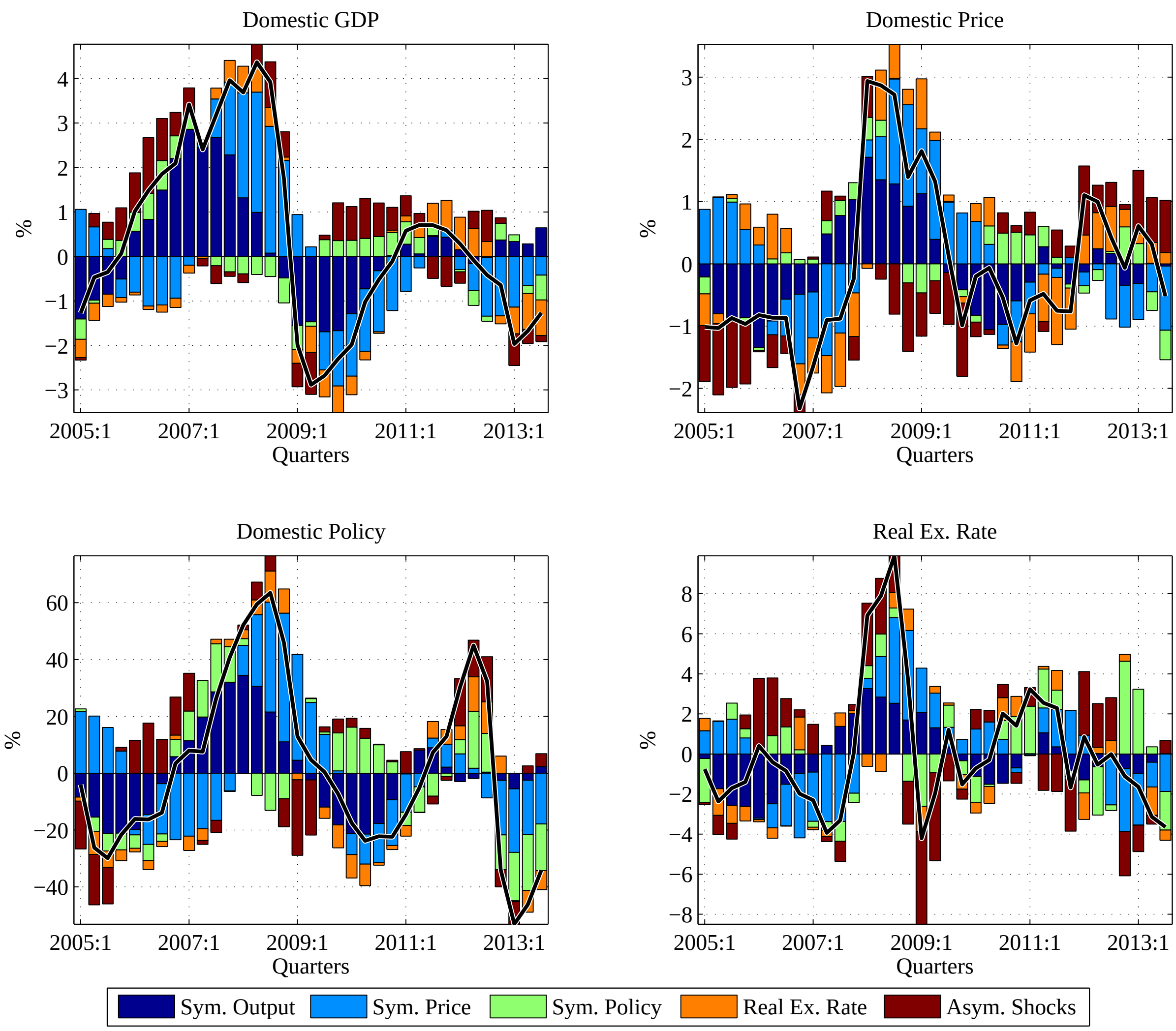


Figure 25: Shocks Contributions – Slovakia

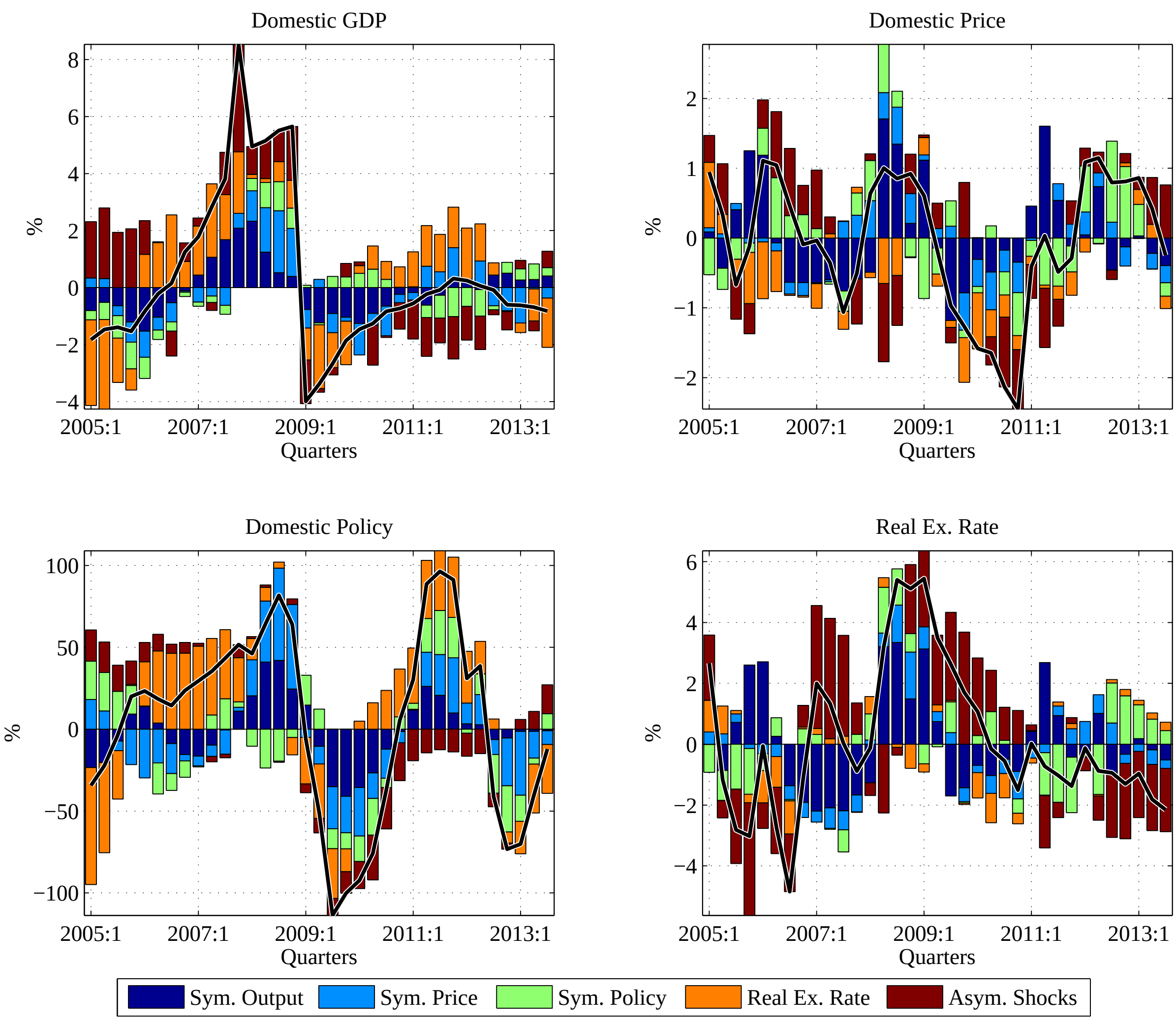


Figure 26: Shocks Contributions – Hungary

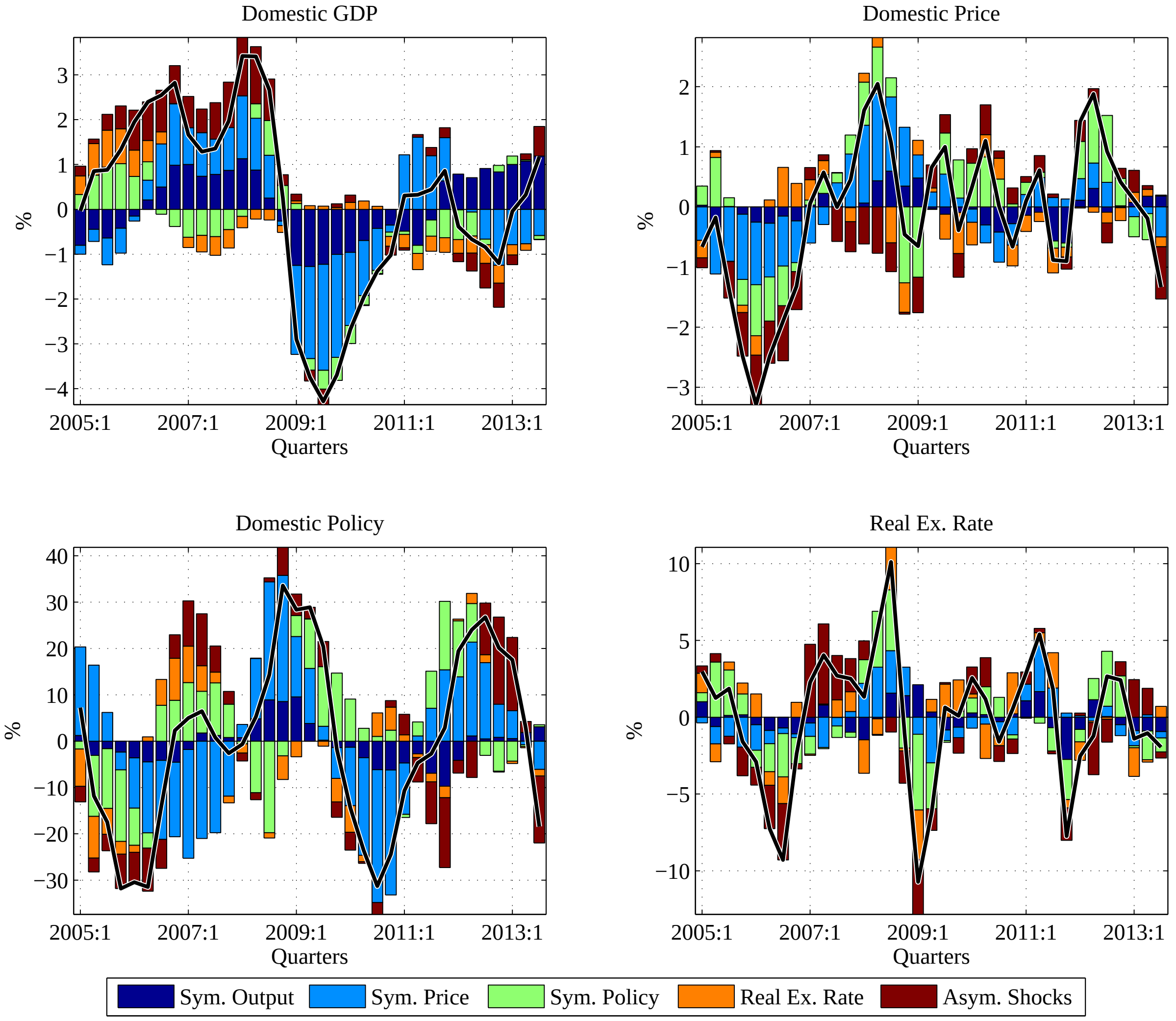


Figure 27: Shocks Contributions – Poland

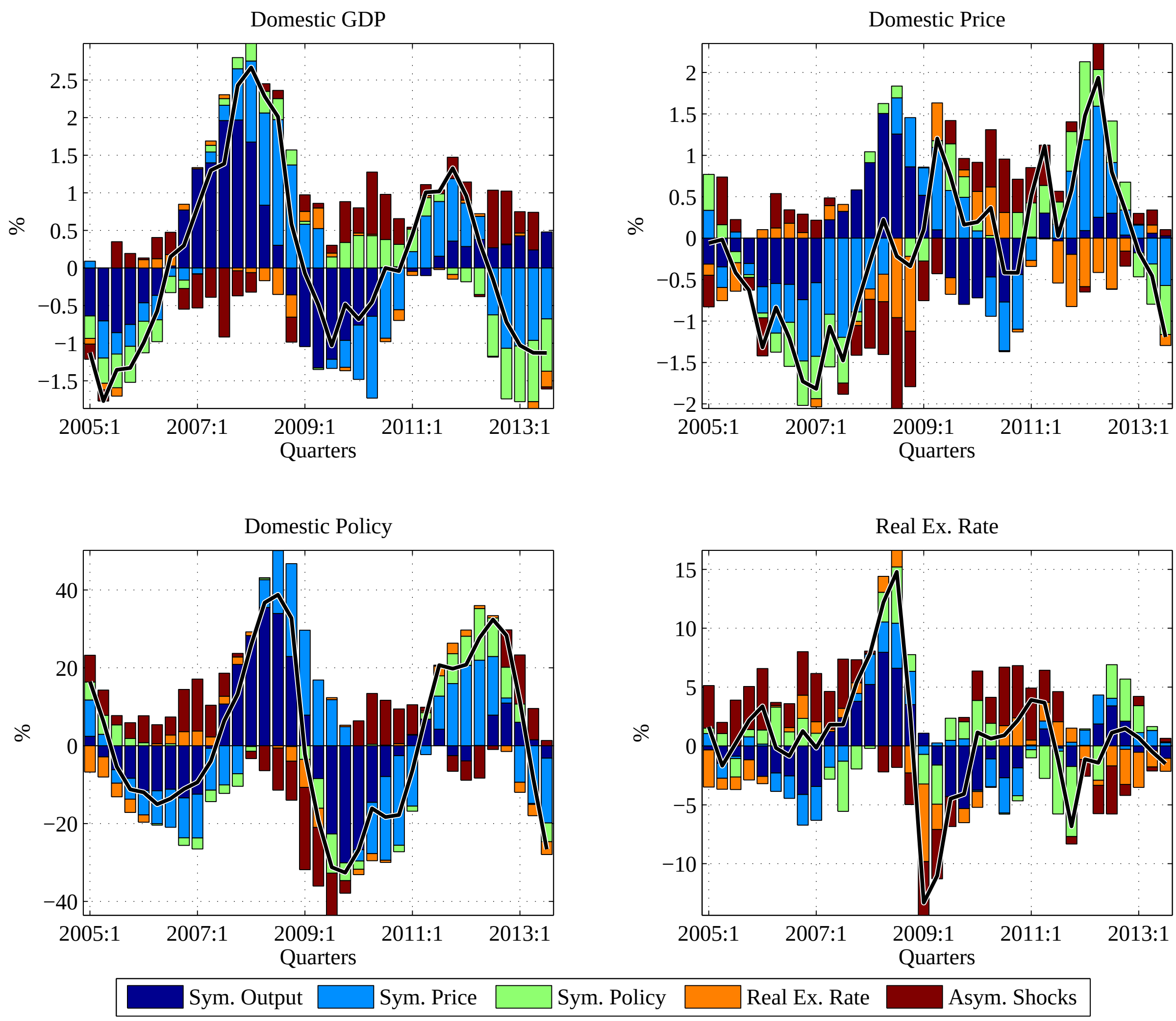


Figure 28: Shocks Contributions – Estonia

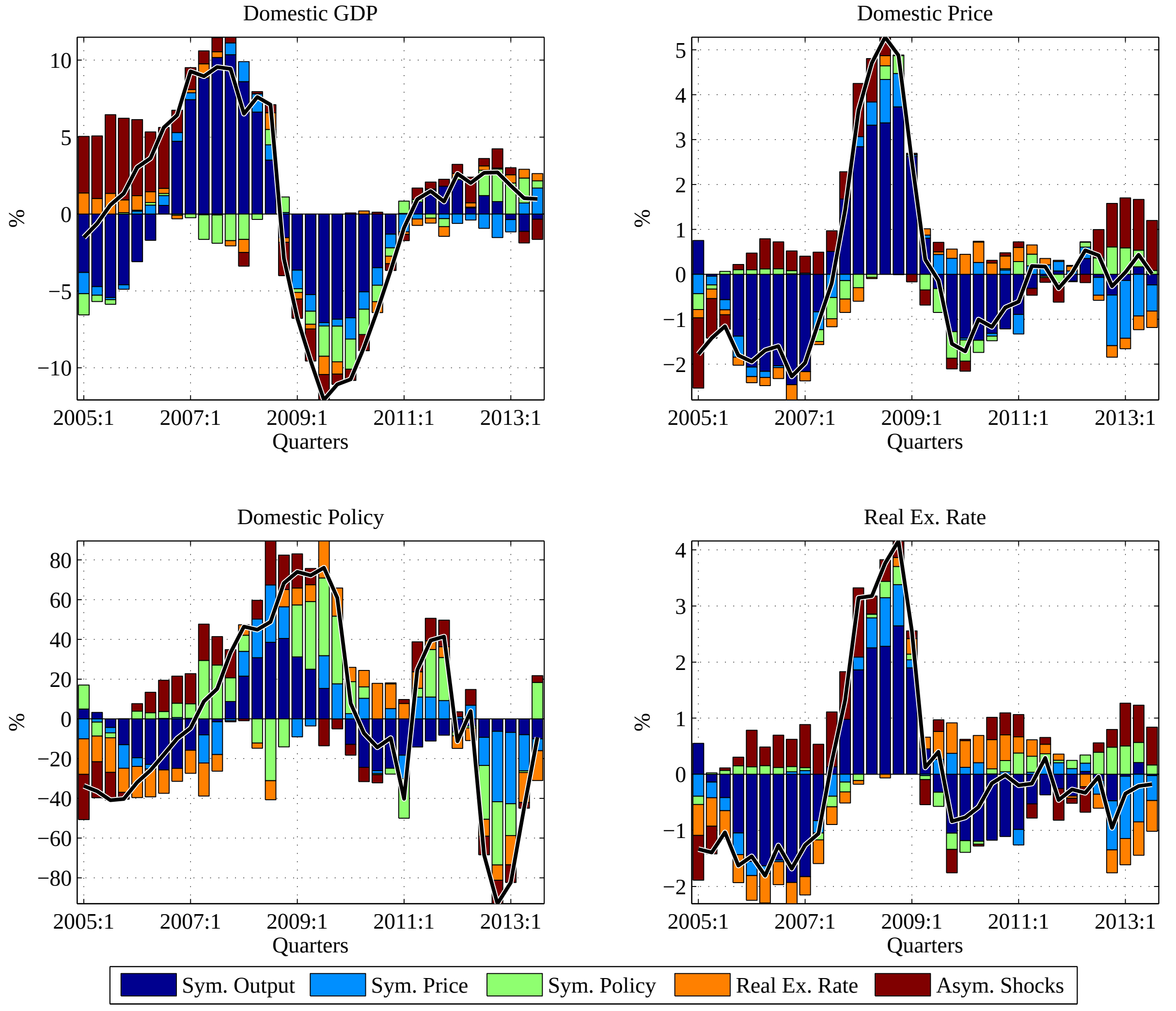


Figure 29: Shocks Contributions – Lithuania

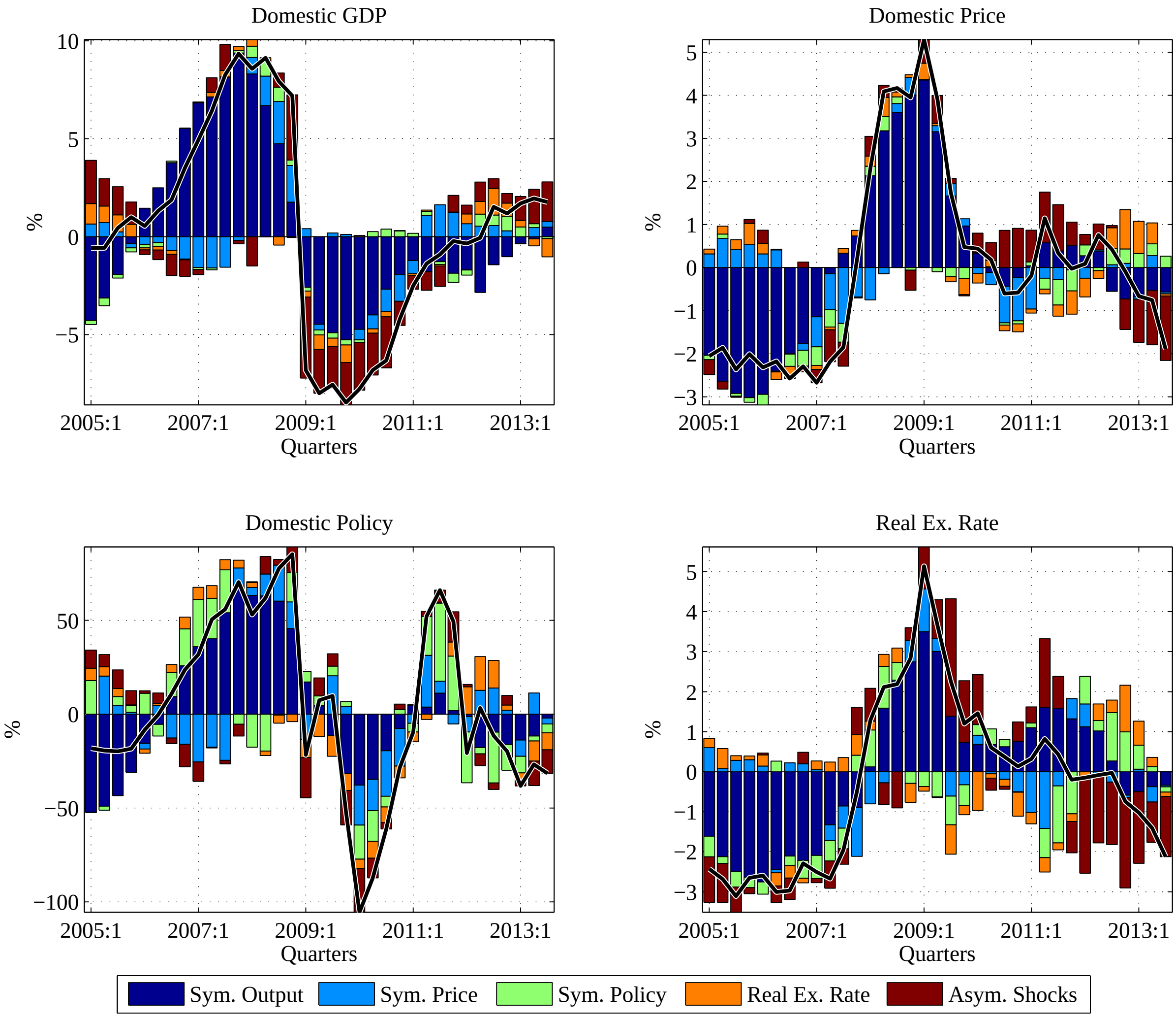


Figure 30: Shocks Contributions – Latvia

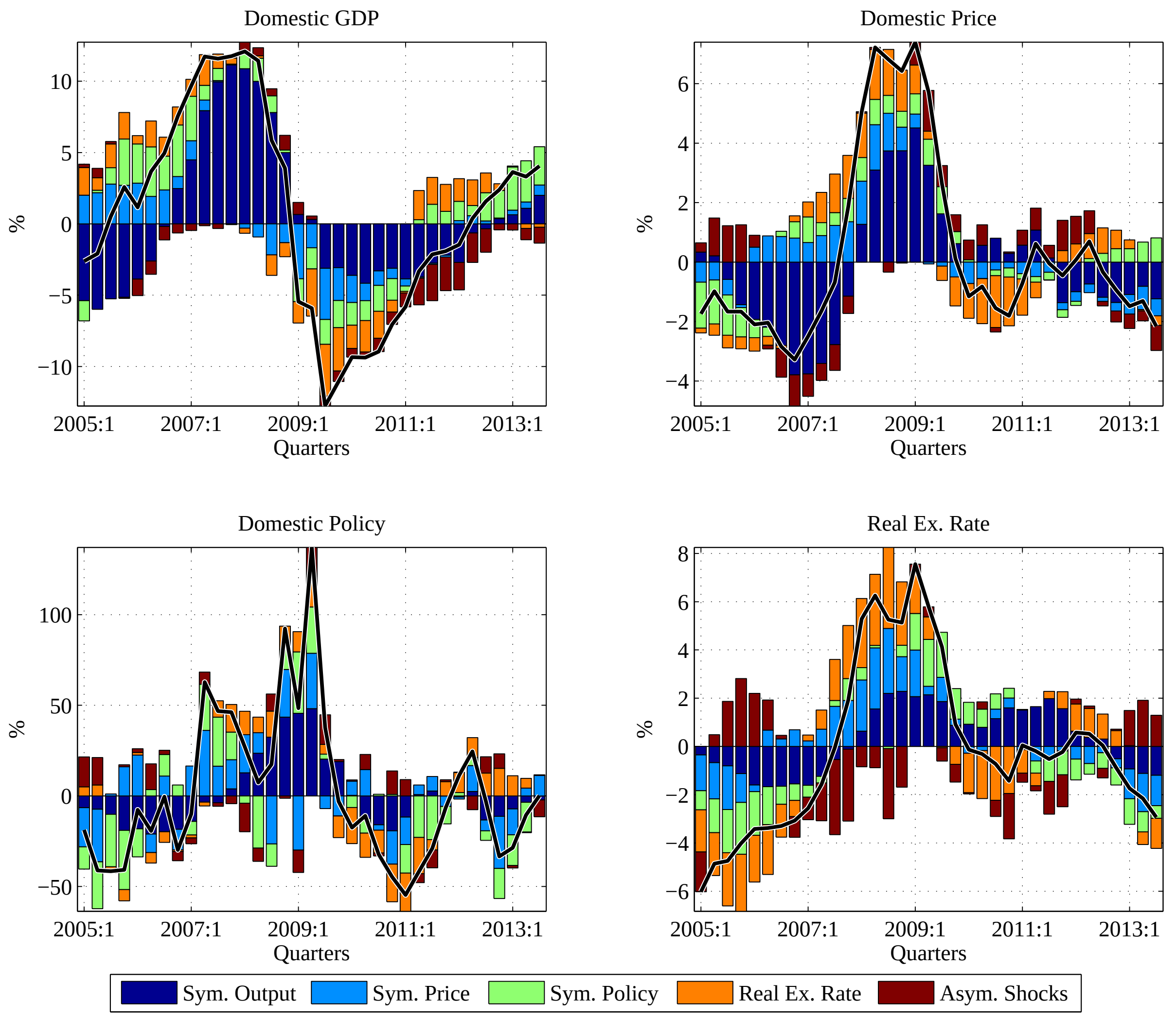


Figure 31: Shocks Contributions – Romania

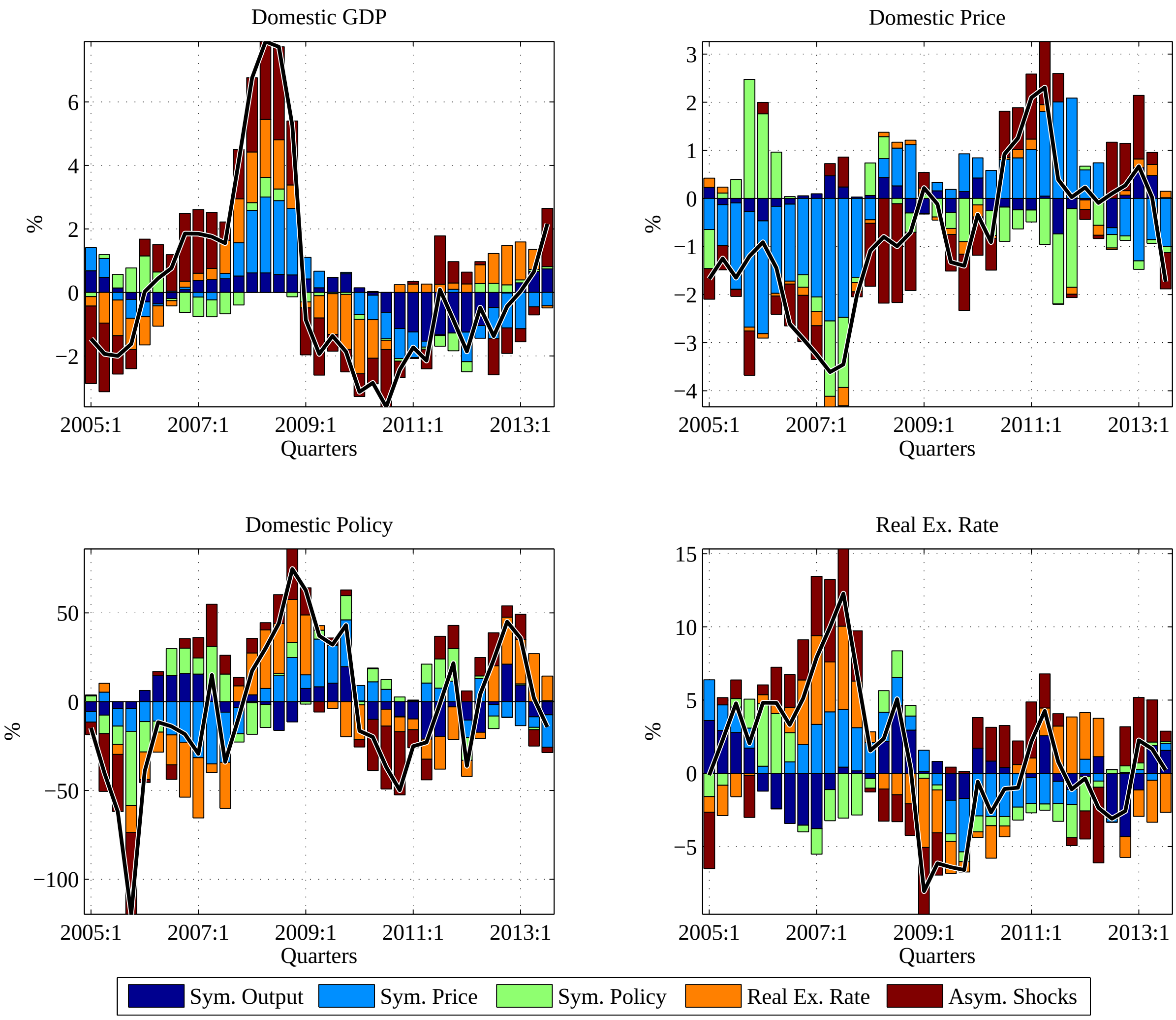


Figure 32: Shocks Contributions – Bulgaria

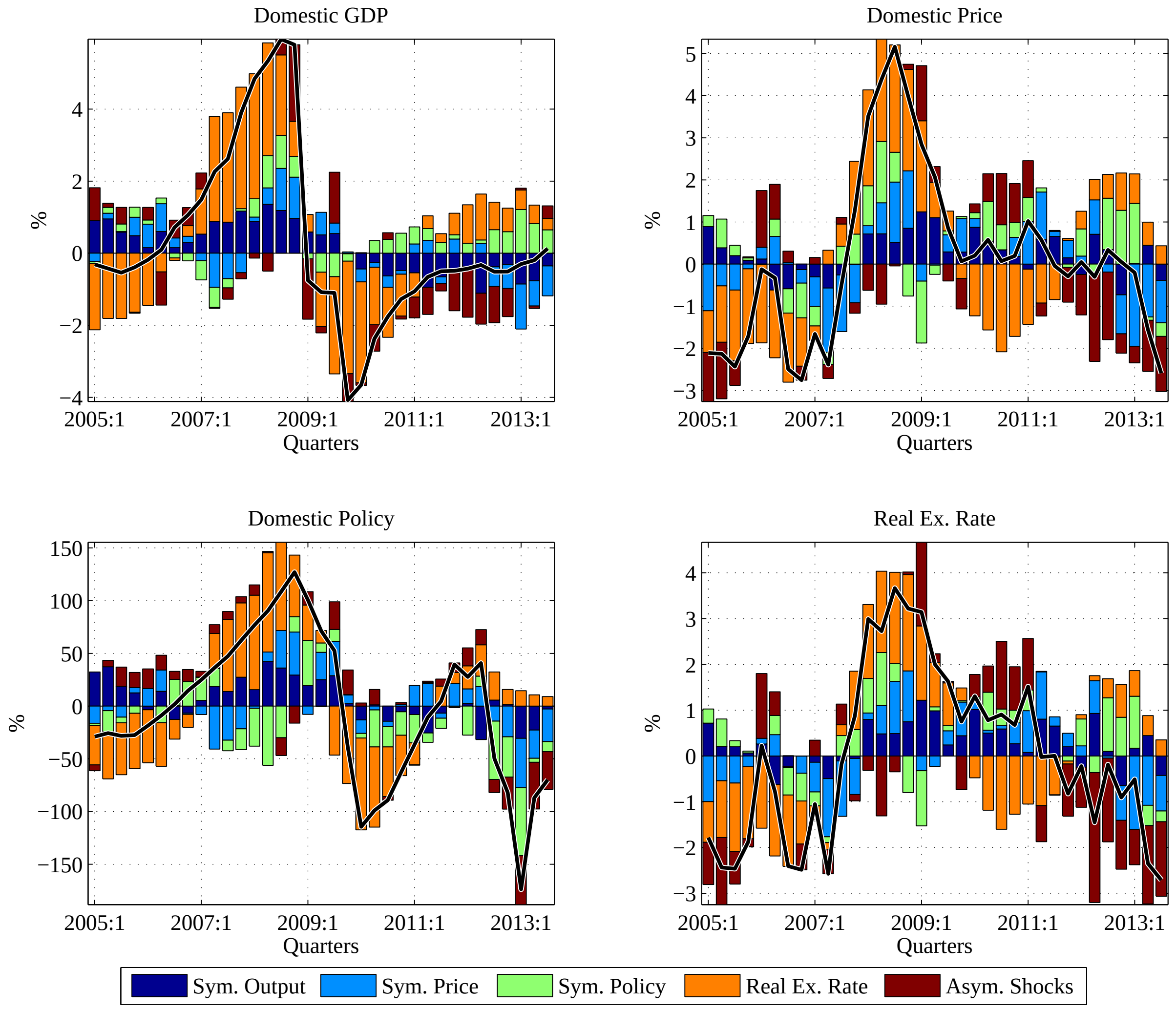


Figure 33: Shocks Contributions – Slovenia